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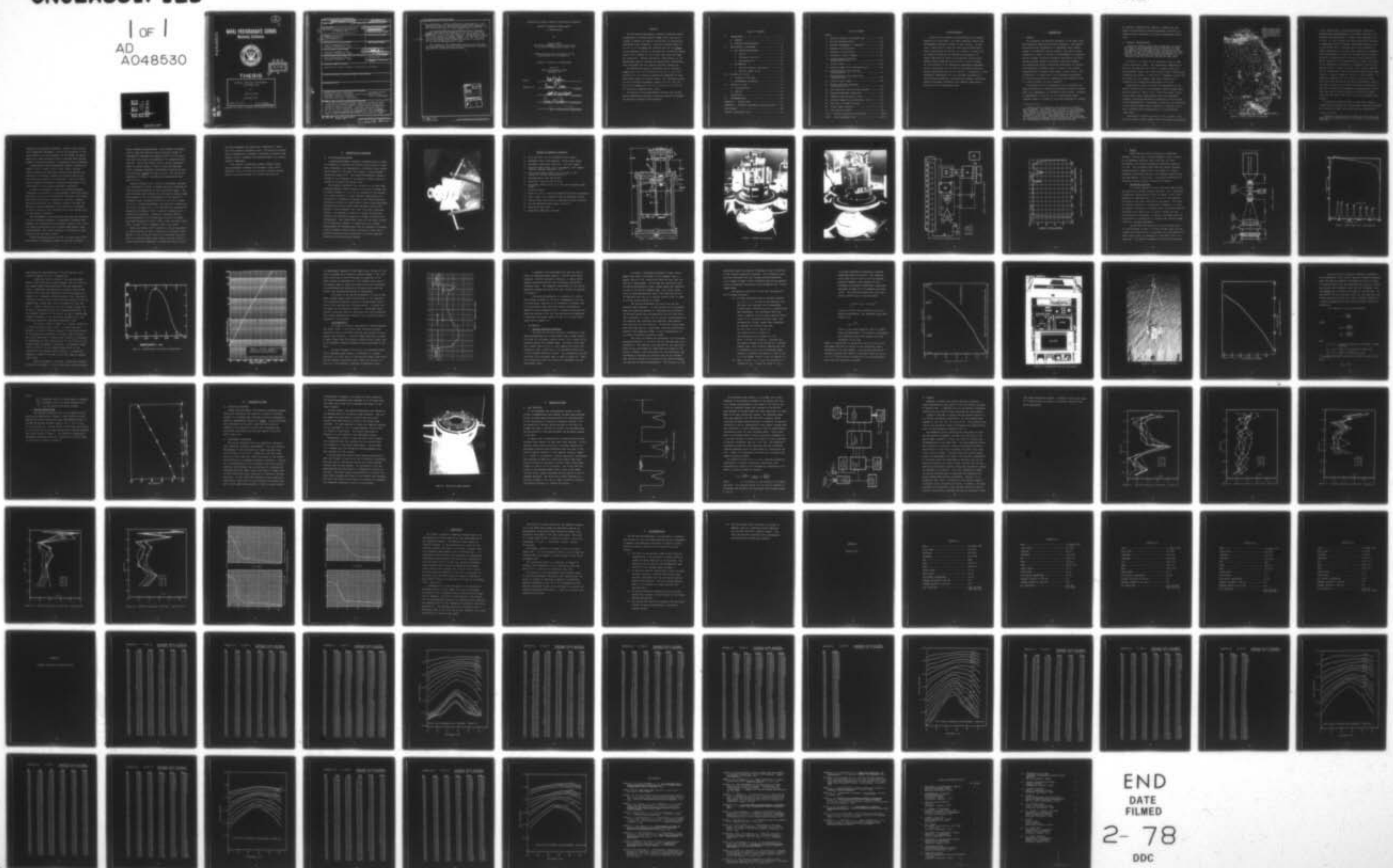

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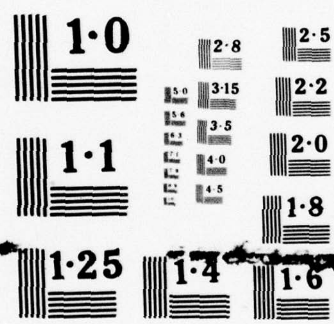

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THESIS

SPECTRAL IRRADIANCE MEASUREMENTS
IN MONTEREY BAY

by

Robert Zafran

September 1977

Thesis Advisors: S. P. Tucker
A. L. Schoenstadt

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The NPS Spectroirradiometer (spectral irradiance meter) incorporates a rotating spectral wedge filter and was developed to measure the spatial distribution of downwelling underwater solar irradiance. Spectral irradiance data in the 402 to 577 nm regime was observed from the R/V Acania at four separate stations in Monterey Bay, California, during August 1976 to depths of 130 m under both clear and foggy

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sky conditions. Diffuse attenuation coefficients, k, for downwelling light at selected wavelength/depth combinations were calculated from the observed spectral irradiances.

436 microwatts sq.cm .00150

The downwelling spectral irradiance values obtained ranged from 4.36 X 10^2 μW/cm^2/nm at 494 nm to 1.50 X 10^{-3} μW/cm^2/nm at 577 nm and are numerically comparable to data from other studies of coastal waters. The calculated values for five selected wavelengths, namely 418, 453, 487, 522, and 557 nm, ranged from .097/m^{-1} at 418 nm to .274/m^{-1} at 557 nm and are representative values.

microwatts/sq.cm

The results of the measurements indicate that the NPS Spectroirradiometer provides a practical method of determining spectral irradiance distributions.

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Spectral Irradiance Measurements
in Monterey Bay

by

Robert Zafran
Lieutenant Commander, United States Navy
B. S., Naval Postgraduate School, 1970

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the
NAVAL POSTGRADUATE SCHOOL
September 1977

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Dean of Science and Engineering

ABSTRACT

The NPS Spectroirradiometer (spectral irradiance meter) incorporates a rotating spectral wedge filter and was developed to measure the spatial distribution of downwelling underwater solar irradiance. Spectral irradiance data in the 402 to 577 nm regime was observed from the R/V Acania at four separate stations in Monterey Bay, California, during August 1976 to depths of 130 m under both clear and foggy sky conditions. Diffuse attenuation coefficients, k, for downwelling light at selected wavelength/depth combinations were calculated from the observed spectral irradiances.

The downwelling spectral irradiance values obtained ranged from 4.36×10^{2} $\mu W/cm^2/nm$ at 494 nm to 1.50×10^{-3} $\mu W/cm^2/nm$ at 577 nm and are numerically comparable to data from other studies of coastal waters. The calculated values for five selected wavelengths, namely 418, 453, 487, 522, and 557 nm, ranged from .097 m^{-1} at 418 nm to .274 m^{-1} at 557 nm and are representative values.

The results of the measurements indicate that the NPS Spectroirradiometer provides a practical method of determining spectral irradiance distributions.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my family, especially my wife Cheryl, for their unselfish support and encouragement during all phases of this project. In addition, I would like to thank all those who provided assistance, particularly my advisor, Dr. Stevens P. Tucker, for his technical guidance and cooperation throughout, Mr. Robert Limes and the Staff of the Computer Science Group, Captain Woodrow Reynolds and the crew of the R/V Acania, Mr. Tom Christian of the Mechanical Engineering Department, and Mr. Pete Wisler and the staff of the Machine Facility. Special appreciation goes to Dr. Arthur L. Schoenstadt, of the Mathematics Department, for his invaluable assistance in establishing mathematical techniques and computer operations enabling equipment calibration and computer computations and plots of the experimental data.

I. INTRODUCTION

A. PURPOSE

The biological and physical processes in the upper ocean are intimately connected with solar radiation. The spatial distribution and transmission of underwater solar radiant energy is an essential optical property that must be fully understood in order to evaluate the performance of underwater optical systems, correlate biological productivity and commercial fishing catches, and predict ocean heat budgets. The downwelling diffuse attenuation coefficient, k, derived from underwater irradiance data, is used for the optical classification of oceanic water masses (Jerlov, 1951). The coefficient, k, refers here to the irradiance attenuation or "vertical extinction" of underwater solar radiation within a given stratum, its units being m^{-1}.

The purpose of this investigation was to determine the depth distribution of downwelling underwater spectral irradiance[1] (E_d) impinging on a horizontal plane surface. Spectral E_d measurements in the 402 to 577 nm wavelength region (visible light) to a depth of 130 m were obtained at a series

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[1]Radiant flux is defined as the time rate of flow of radiant energy. The radiant flux incident on an infinitesimal element of surface containing the point under consideration, divided by the area of that element, is defined as irradiance E, its units being power per unit area, e.g., watts/m^2 or watts^3/cm^2. The downwelling, E_d, and upwelling, E_u, irradiance are defined as the flux per unit area collected on a horizontally oriented cosine collector surface.

of stations in Monterey Bay (Figure 1) between June and August 1976 employing a spectroirradiometer (spectral irradiance meter) developed at the Naval Postgraduate School (NPS).

B. PREVIOUS INVESTIGATIONS

> "Among the subjects which Arago recommended to sailors for study is the transparency of the sea and its color. The depth at which one sees objects in the sea is most interesting, but unfortunately there are few direct observations, I mean, of course, direct experiments, and not more or less conjectural observations in which it is 'believed' that the bottom of the sea has been seen."

So wrote P. A. Secchi in his scientific diary in 1865 (Cialdi and Secchi, 1865). His experimental immersions of discs of varying sizes and colors in coastal waters off Civitavecchia, Italy, did in fact product direct observations concerning the limits of visibility of submerged objects, and the Secchi disc is commonly used today--especially by biologists--in determining transparency of the sea.

Experimental studies involving the measurement of the spatial distribution of the underwater radiant energy field were initiated by Bertel (1911) [DuPre and Dawson (1961)]. Using a small quartz spectrograph, Bertel photographed naturally occurring underwater illumination, and his qualitative determination of wavelength distribution and direction of the radiant energy field, although not complete, did in fact illustrate some characteristics of the underwater light field.

Starting with Shelford and Gail (1922), Knudsen (1922), Poole and Atkins (1962), Beebe (1934), Pettersson and Landberg

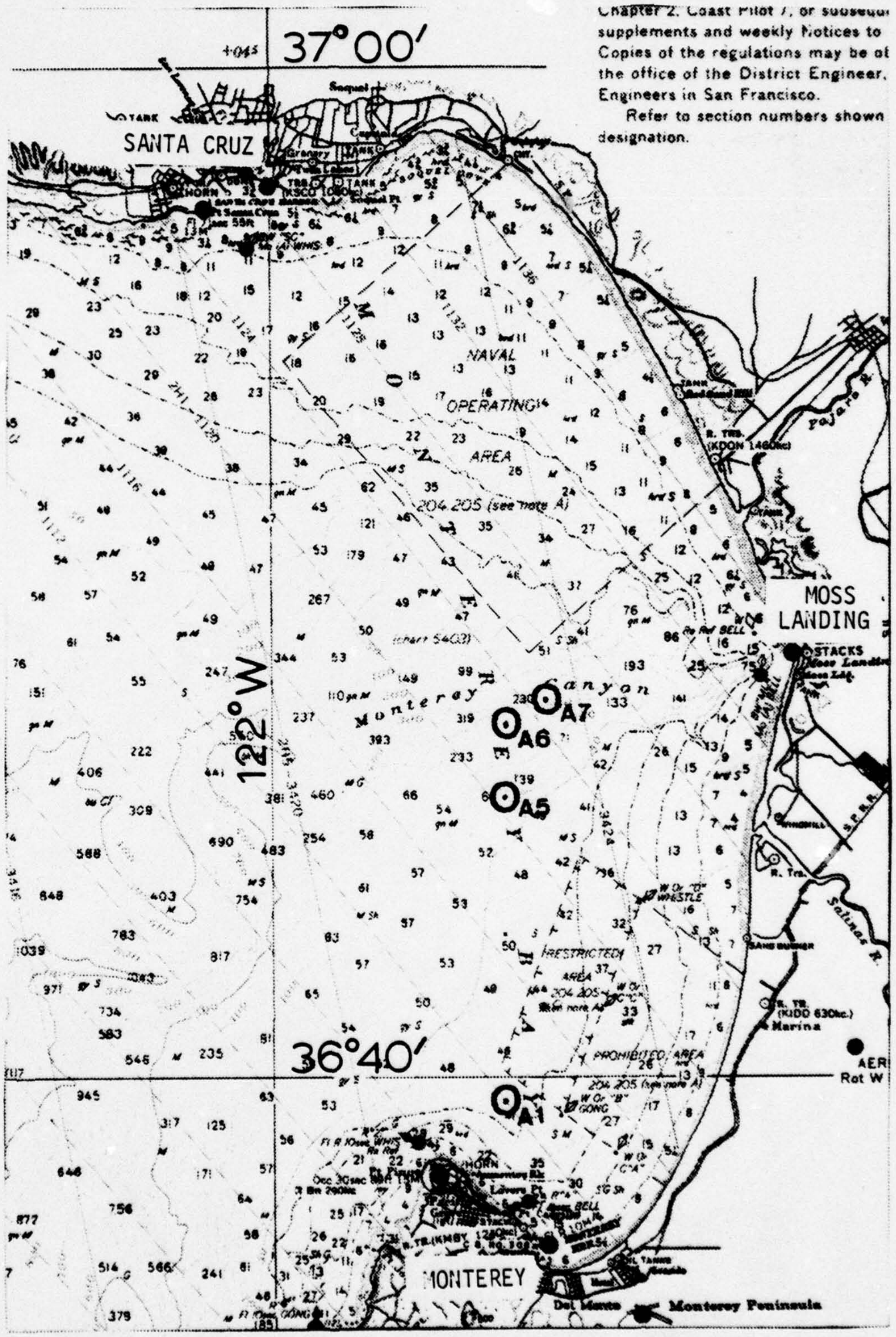


Figure 1. Station locations in Monterey Bay

(1934), among others, utilized photographic techniques, photometers, and spectrographs as the primary devices to investigate the penetration of visible solar radiation into the sea. In 1933 Utterback and Boyle devised and utilized a submersible device utilizing a calibrated photronic cell in conjunction with a rotating light filter assembly to measure penetration of visible solar radiation in seawater. Their measurements in waters off Southern Alaska revealed evidence of layering within the water column resulting in marked variations in the penetrability of light. The cause of the layering was attributed to discharge of rivers and glacial effects. Oster and Clarke (1935) using a combination of photoelectric cells and filters examined light penetration in Atlantic waters in the 300 to 700 nm region. An excellent comparison of their results (Oster and Clark, 1935) with data obtained by previous investigators reveals the lowest values of the diffuse attenuation coefficient, k, then yet obtained from the Sargasso Sea approaching or even less than that of distilled water as obtained by Sawyer (1931) in the case of the violet, red, blue and green components.

It should be noted that most of these early studies focused on the variation and penetration of spectral radiance[2] as a function of depth and as such were not specifically

[2] Radiance is defined as the radiant flux per unit solid angle per unit projected area of a surface, its units being $W/m^2/nm/sr$.

concerned with spectral irradiance. However, they did provide fundamental knowledge of the optical properties of the upper layers of the sea necessary for the design and implementation of more advanced devices, including those devices capable of direct measurement of underwater solar irradiance.

Using advanced spectrophotographic methods, LeGrand and LeNoble (1954), Ivanoff (1955), Tyler (1958), and many others, expanded the knowledge concerning the spectral distribution of underwater radiance including extention into the ultraviolet portion of the spectrum. Jerlov and Koczy (1951) extended monochromatic irradiance measurements to an ocean depth of 500 m using photographic techniques.

A distinct advantage of using the spectrophotographic techniques is the ability to simultaneously record the entire spectrum as well as the variabilities existing in the irradiance field at the time of exposure of the film. However, particular attention as to exposure timing, film types and densities, and photogrammetric data reduction is required in order to obtain a true representation of the desired optical properties of seawater.

The advancements in photoelectric detectors and electronic circuitry permitted expansion of underwater irradiance measurements by electro-optical techniques. Sasaki, et al. (1955) and Clarke and Wertheim (1956) obtained measurements using photomultiplier (PM) tubes possessing the advantage of high sensitivity at low light levels.

Clarke and Wertheim were the first to report deep (580 m) measurements of irradiance between 320 and 650 nm using a

direct reading bathyphotometer. They obtained irradiance data at night and observed almost continual flashes of luminescence from deep sea organisms below 300 m in depth that were 1000 times the intensity of the background illumination. Jerlov and Piccard (1959), using a bathyphotometer of similar design to that of Clarke and Wertheim (1956), measured underwater illumination during dives with the bathyscaph Trieste off Capri in 1957. The device was calibrated in terms of irradiance, and observations were made to 300 m.

Kampa and Bowden (1957) utilized a photometer equipped with interference filters to measure absolute irradiance of bioluminescence generated in sonic-scattering layers. The same instrument was modified and later used by Bowden, Kampa and Snodgrass (1960) for measurements of the spectra of underwater solar irradiance from 421 to 540 nm to a depth of 400 m. A prism monochromator that optically scanned the 400 to 600 nm range with a 10 nm bandwidth was developed by Hubbard and Richardson (1959) to measure irradiance as a function of wavelength. Underwater irradiance meters, spectroradiometers, and integrating irradiance recorders have been developed by Jerlov (1965), Tyler and Smith (1966, 1968), Duntley (1963), Snodgrass (1961), and others.

Neefus and McLeod (1974) studied the optical properties of natural waters off Bimini, Woods Hole, and Boston Outer Harbor in 1974 utilizing a meter that determines the radiance in a vertical plane, scans several vertical planes to obtain directional components of irradiation about a point,

and then integrates the directional components to obtain the total spectral irradiance value. The spectral distribution is obtained by a rotating, continuously variable interference filter to separate the collected light into visible spectral components.

Local studies of underwater radiant energy include those conducted by Bassett and Furminger (1965), and by Michelini (1971), who made some spectral radiance measurements in near-shore waters off southern Monterey Bay.

II. DESCRIPTION OF EQUIPMENT

A. NPS SPECTROIRRADIOMETER

A spectroirradiometer (spectral irradiance meter) having the capability to measure the spectral distribution of underwater irradiance, E_d, impinging on a horizontal plane surface was developed by the author and Stevens P. Tucker between January and August 1976. The spectroirradiometer (Figures 2 through 6) is a redesign of the spectral radiance meter developed by Michelini and Tucker (1971).

The original photometer unit, housed in a 30.48-cm long aluminum pressure vessel having a 1.91-cm wall thickness and an inside diameter of 15.24 cm, was modified by the addition of a cosine collector to allow complete hemispherical (2π) collection of underwater irradiance in the visible spectrum. The cosine collector is constructed of white, semi-translucent Plexiglas cast acrylic sheet (Rohm and Haas, Type W-2447) having a 5.08-cm diameter (20.27 cm^2) flat disc collecting surface. Its geometry is based on a design developed and tested at the Visibility Laboratory, Scripps Institution of Oceanography. The transmittance curve for the cosine collector as depicted in Figure 7 is relatively flat, having approximately 92% transmittance over the spectrum of interest. A newly designed photomultiplier electronic circuit and a pressure transducer were incorporated to provide improved sensitivity and direct depth readout.

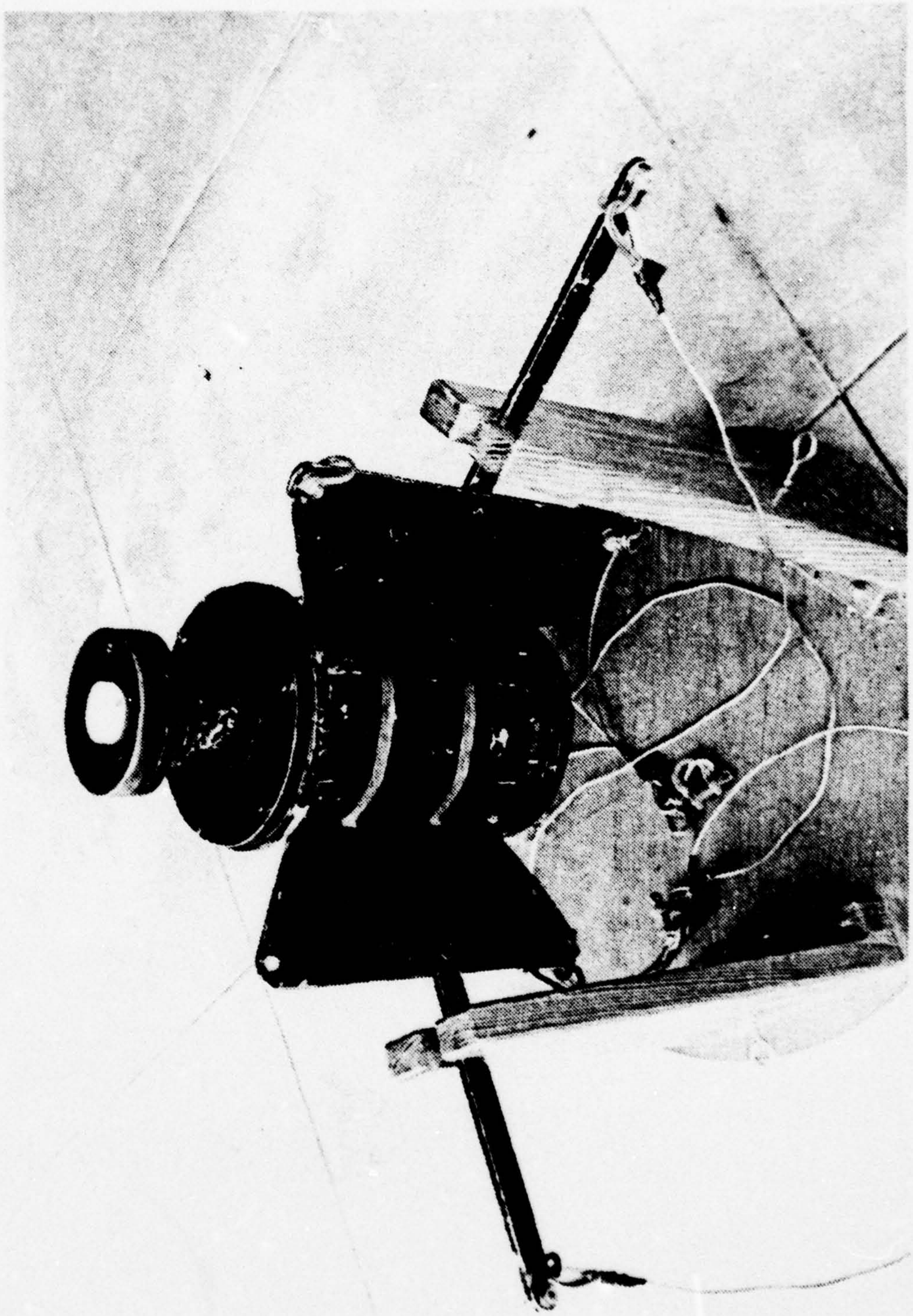


Figure 2. NPS Spectroirradiometer

Keylist to Figures 3 through 6

A. 10.16 cm thick, 10.16 cm diameter Pyrex window.

B. Achromatic lens, 33 mm diameter, 100 mm focal length.

C. Achromatic microscope objective, 3 mm focal length.

D. Spectral wedge filter, 10.16 cm diameter, 180° segment. (Optical Coating Laboratory, Inc.).

E. Filter drive motor, Model 41-25, 36 rpm, 35 Vdc reversible (Hansen Manufacturing Co.).

F. Photomultiplier tube (EMI 9524B).

G. Electronic circuitry for PM tube.

H. Burr-Brown, Model 520/25, ± 15 Vdc dual regulated power supply.

I. Mu-metal shield.

J. Mecca, No. 2047, seven-pin underwater electrical connector.

K. Venus, Model K-15, regulated high voltage power supply.

L. Rohm and Haas, type W-2447, translucent cosine collector.

M. Six Vdc regulated power supply, LM 340-6.

N. Transistor, Hep 2N5013.

O. Operational Amplifier, NE-536T.

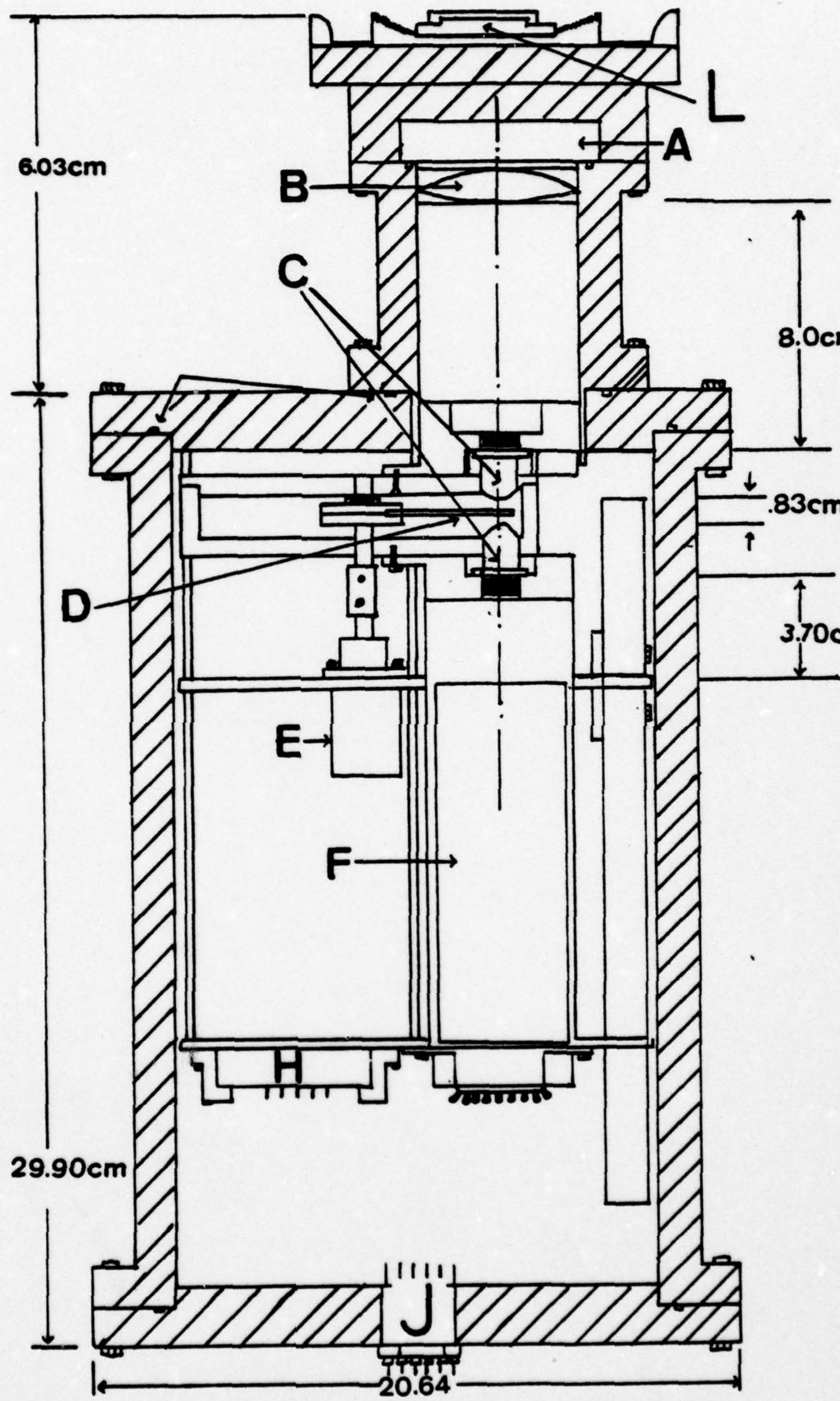


Figure 3. General arrangement of Components

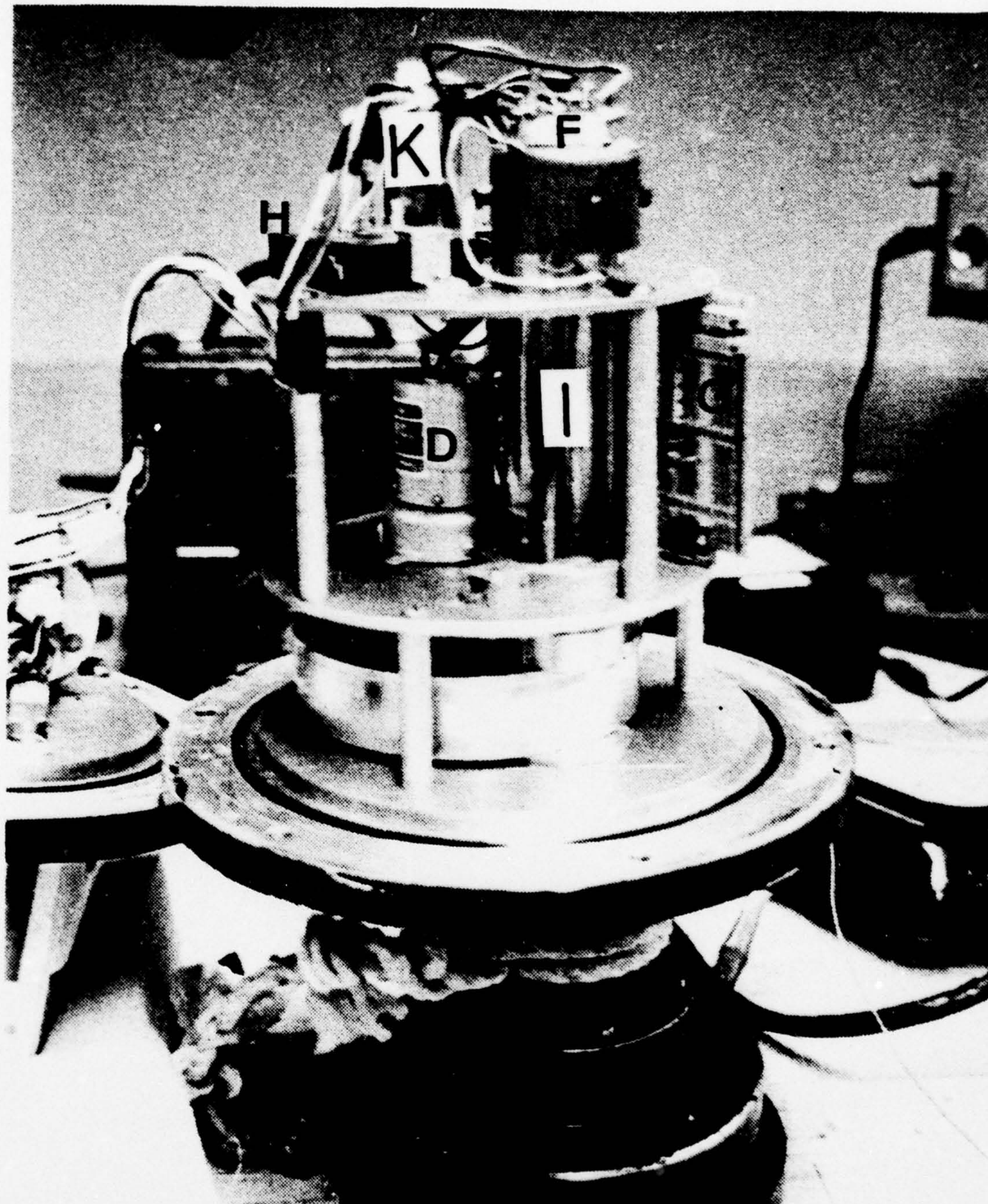


Figure 4. Hardware and electronics

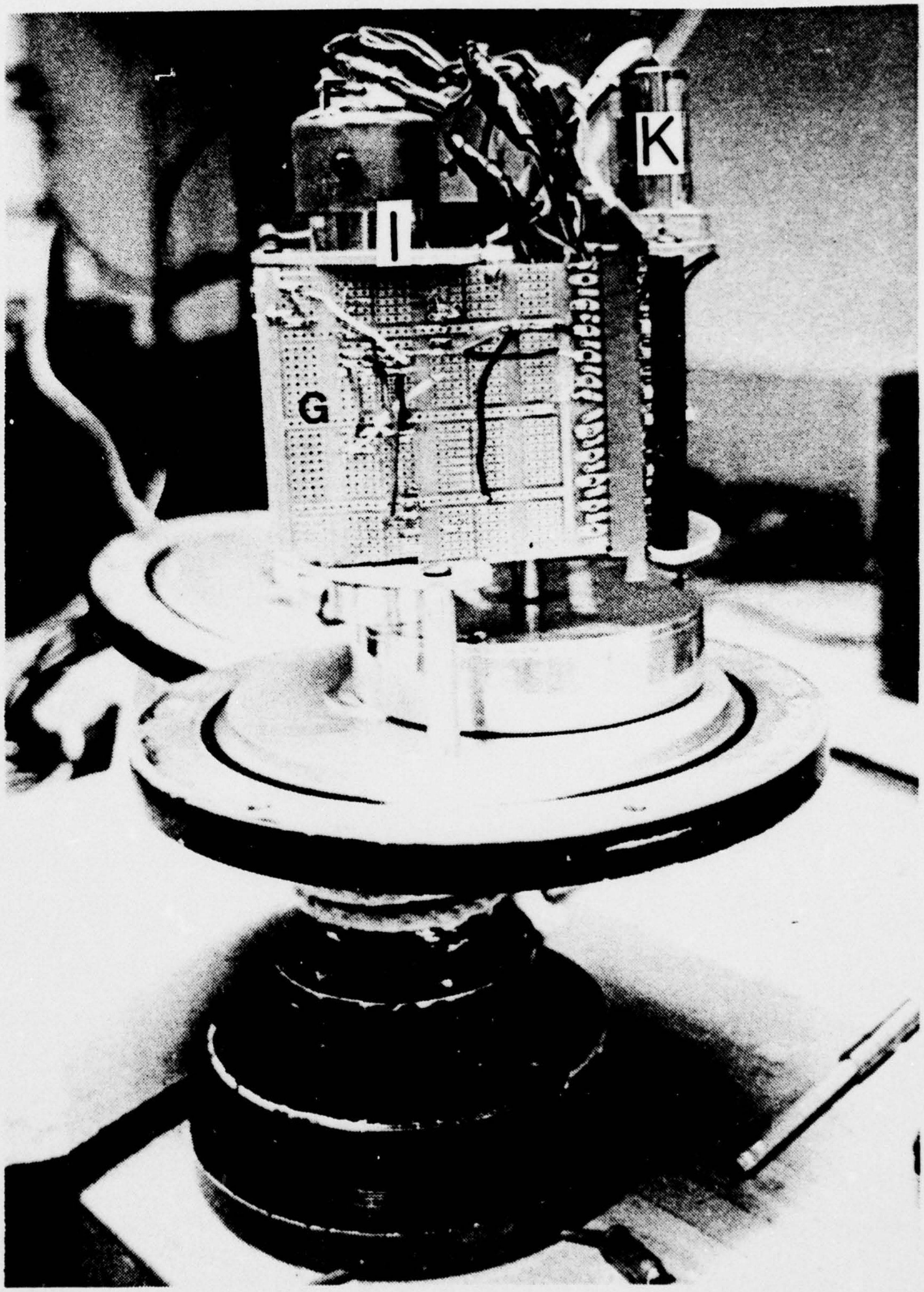


Figure 5. Hardware and electronics

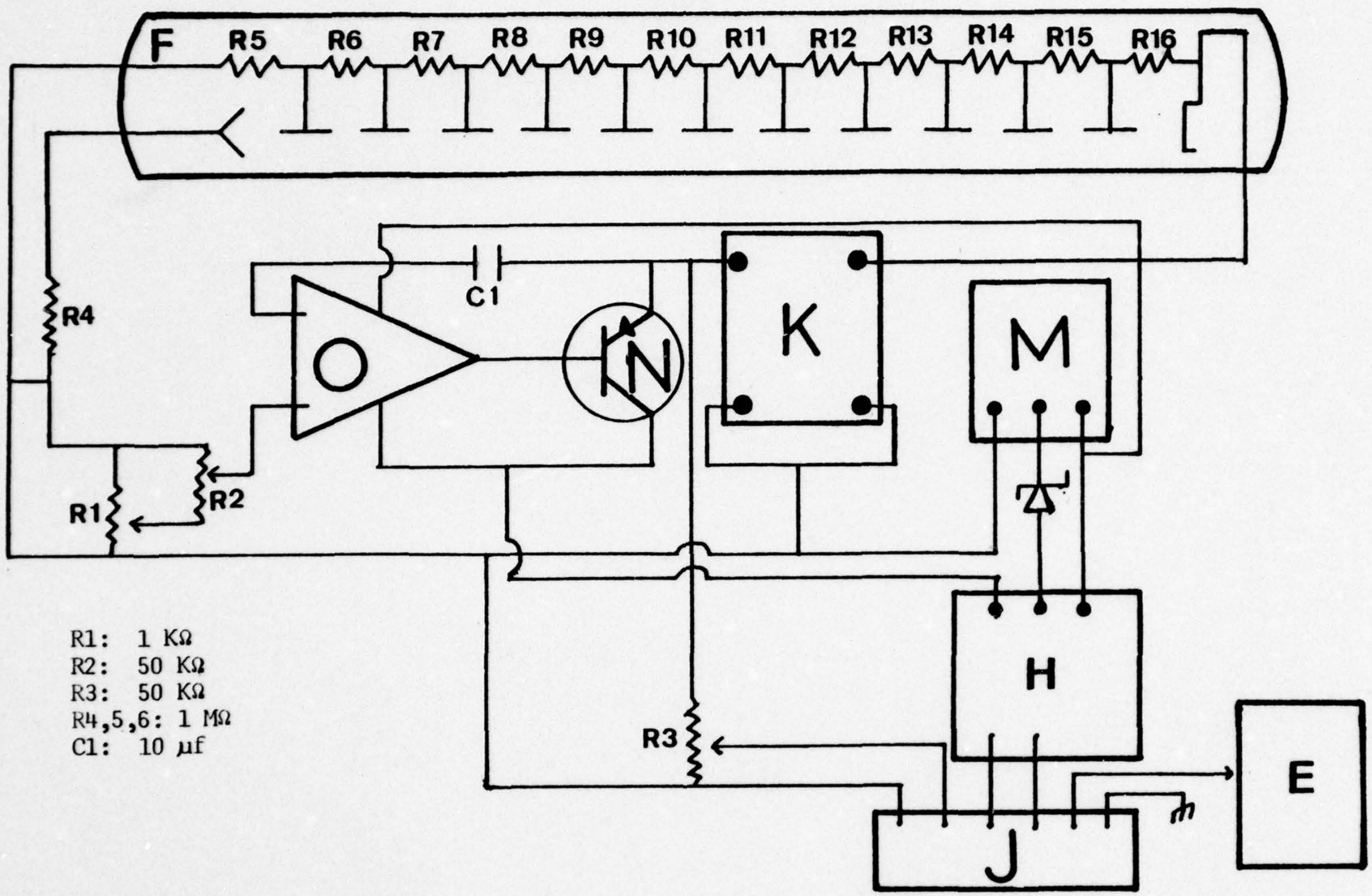


Figure 6. Electronic circuit diagram

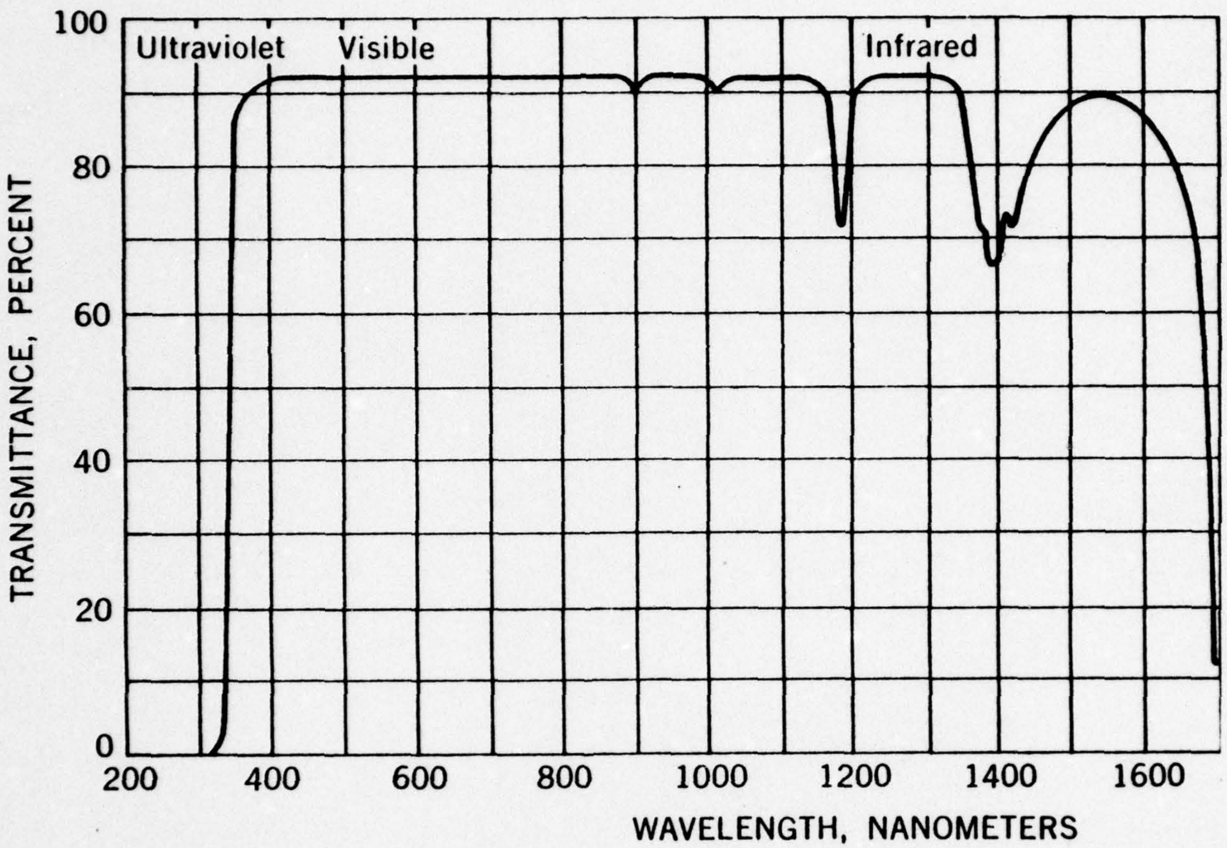


Figure 7. Cosine collector material transmittance curve

1. Optics

Light from the cosine collector is transmitted through a 1.91-cm thick, 10.16-cm diameter window, focused by an achromatic objective lens (F=100 mm), and then collimated by an inverted achromatic microscope objective (F=3 mm). The collimated light beam then passes through a rotating spectral wedge filter, is diverged by a second achromatic microscope objective, and impinges directly upon the photocathode of a PM tube. A functional description of the entire optical system is depicted in Figure 8.

2. Photometer Circuitry

A 10.16-cm diameter half-disc spectral wedge filter, manufactured by Optical Coating Laboratory, Inc., having the transmission characteristics shown in Figure 9 with a half bandwidth of approximately 17 nm, is used in the spectral filtering of the light collected by the optics. The filter is directly coupled to a continuously rotating D. C. motor. The speed of the motor is variable and is controlled from the instrument rack aboard ship in order to obtain the scan rate desired for recording. A specific wavelength band can be selected for presentation by stopping the spectral wedge filter at a desired wavelength.

An EMI 9524B PM tube with a 23 mm end window and S-11 photocathode is used. The high voltage supply for the cathode and dynode circuit is provided by a Venus Model K-15 power supply, which is operated as a high gain (100:1) dc amplifier. The spectral response of the S-11 photocathode

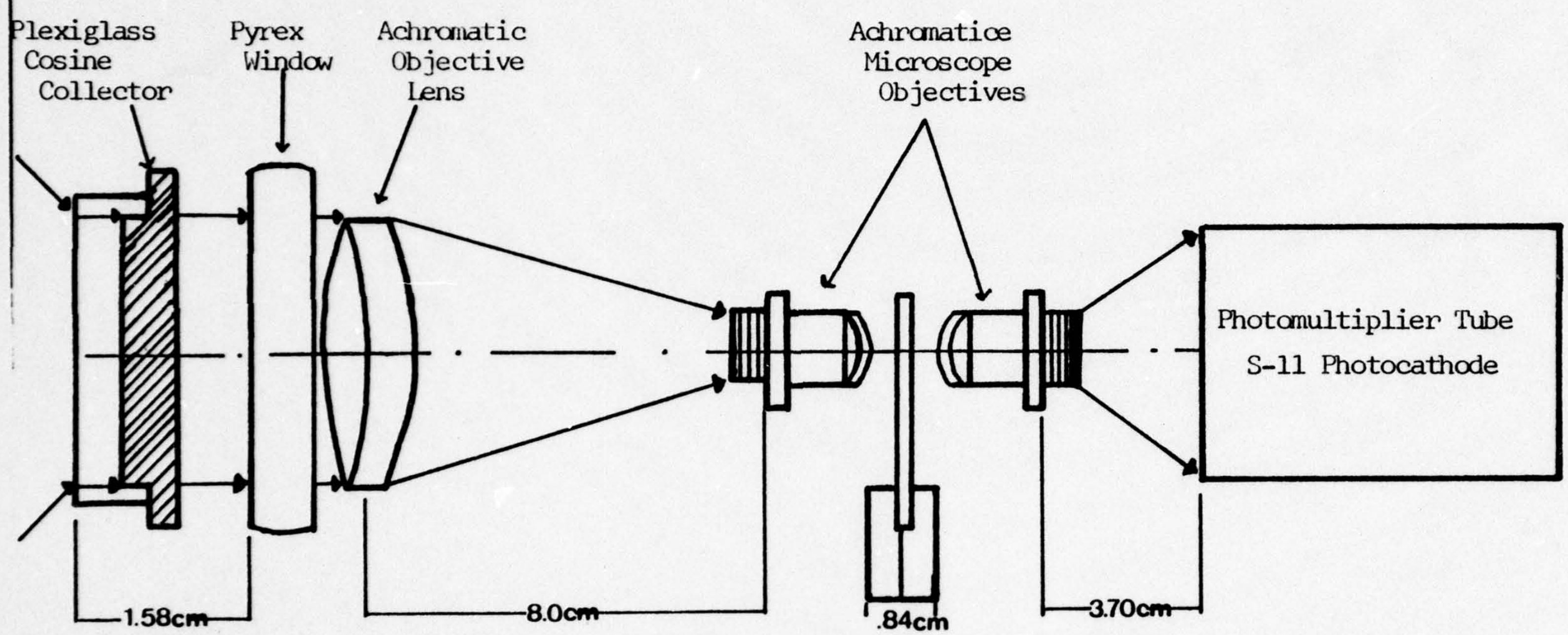


Figure 8. Optical system

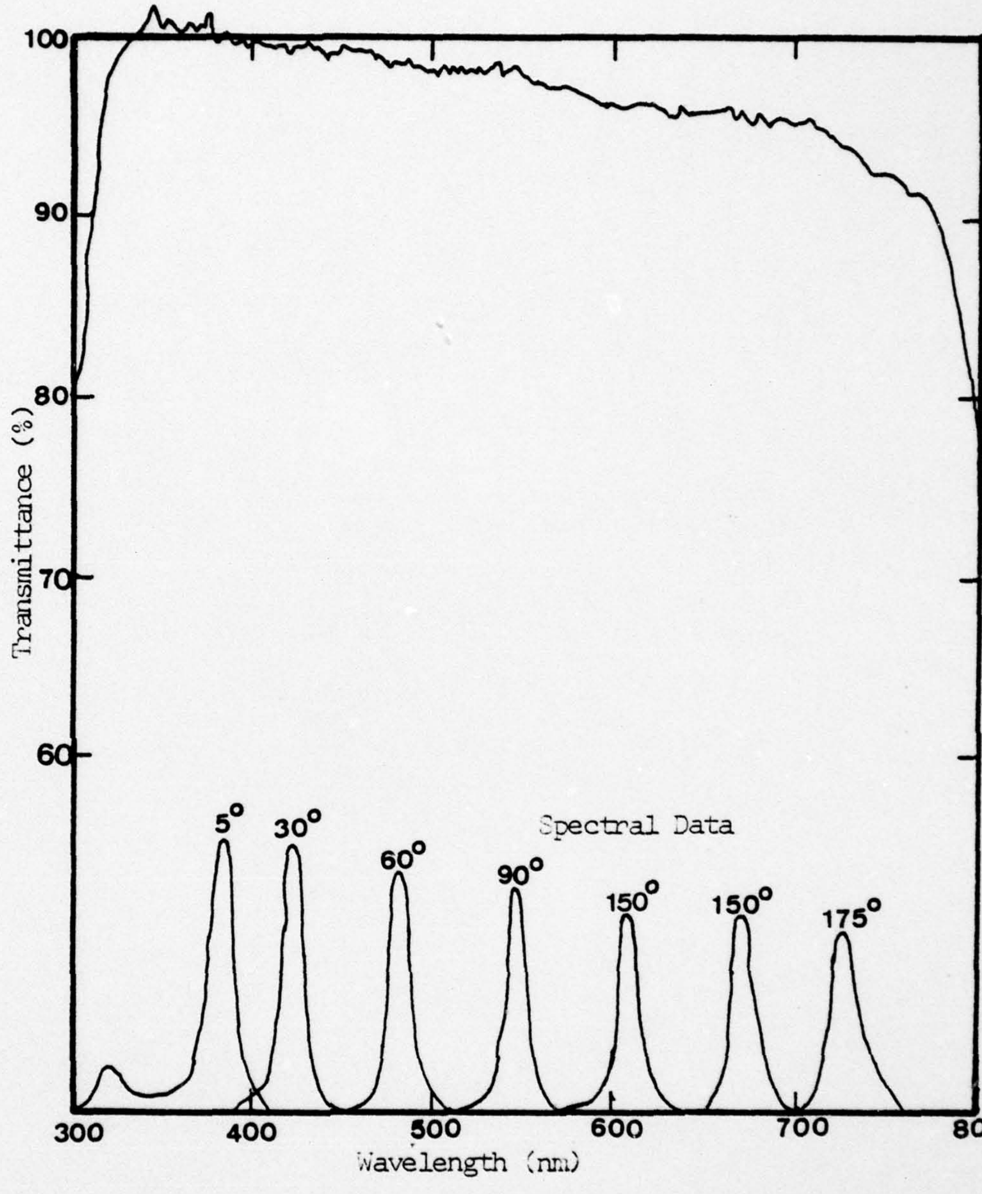


Figure 9. Spectral wedge filter characteristics

and sensitivity characteristics of the PM tube are illustrated in Figures 10 and 11, respectively.

During the initial testing of the spectroirradiometer it was noted that at depths greater than 25 m the output signal became indistinguishable from the background noise. Considering the sensitivity available from the EMI 9524B PM tube, the depth capability should have greatly exceeded 25 m. Subsequent troubleshooting of the electronics indicated that the circuit being used was limited in that the maximum high voltage that could be obtained was less than 800 V. Figure 11 shows that with this cathode voltage the PM tube is operating far below its maximum sensitivity. As the original circuitry did not permit as high a cathode high voltage as desired, a new circuit was designed by Mr. Tom Christian, Mechanical Engineering Department, NPS.

The circuit shown in Figure 6 is a modern version of a concept devised by Sweet (1946). A closed loop servo operation is used to maintain constant PM tube anode current in the presence of variations in incident light intensity. The circuit maintains a constant anode current by increasing or decreasing the high voltage applied to the PM tube as the incident light decreases or increases. The applied voltage (-200 to -1500 V) is then roughly proportional to the logarithm of the incident light intensity. A logarithmic response is needed to provide for the wide range of ambient light levels.

Other advantages of utilizing a logarithmic response include the following: 1) In the event that the photocathode

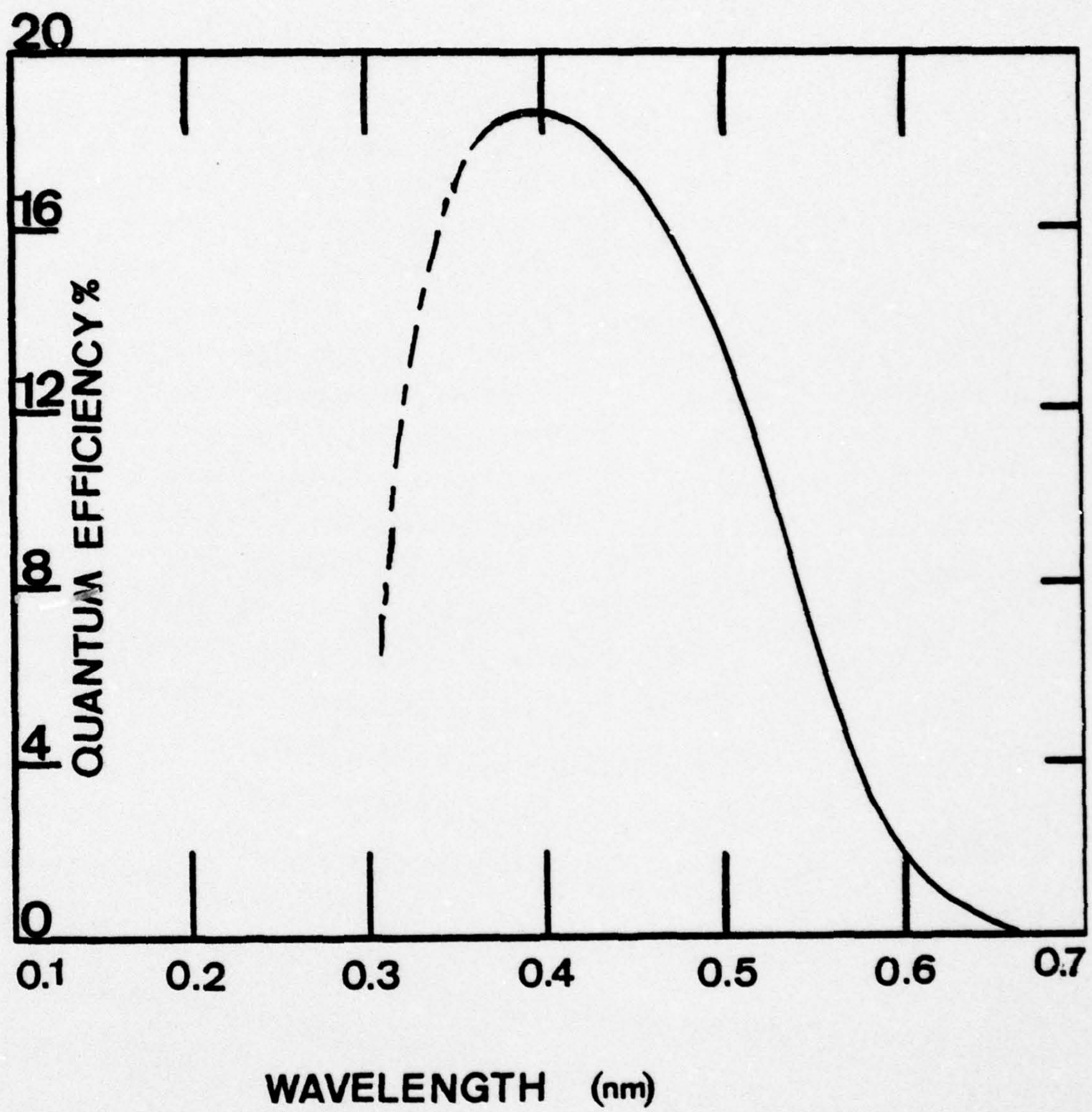


Figure 10. Photomultiplier Tube Spectral Characteristics

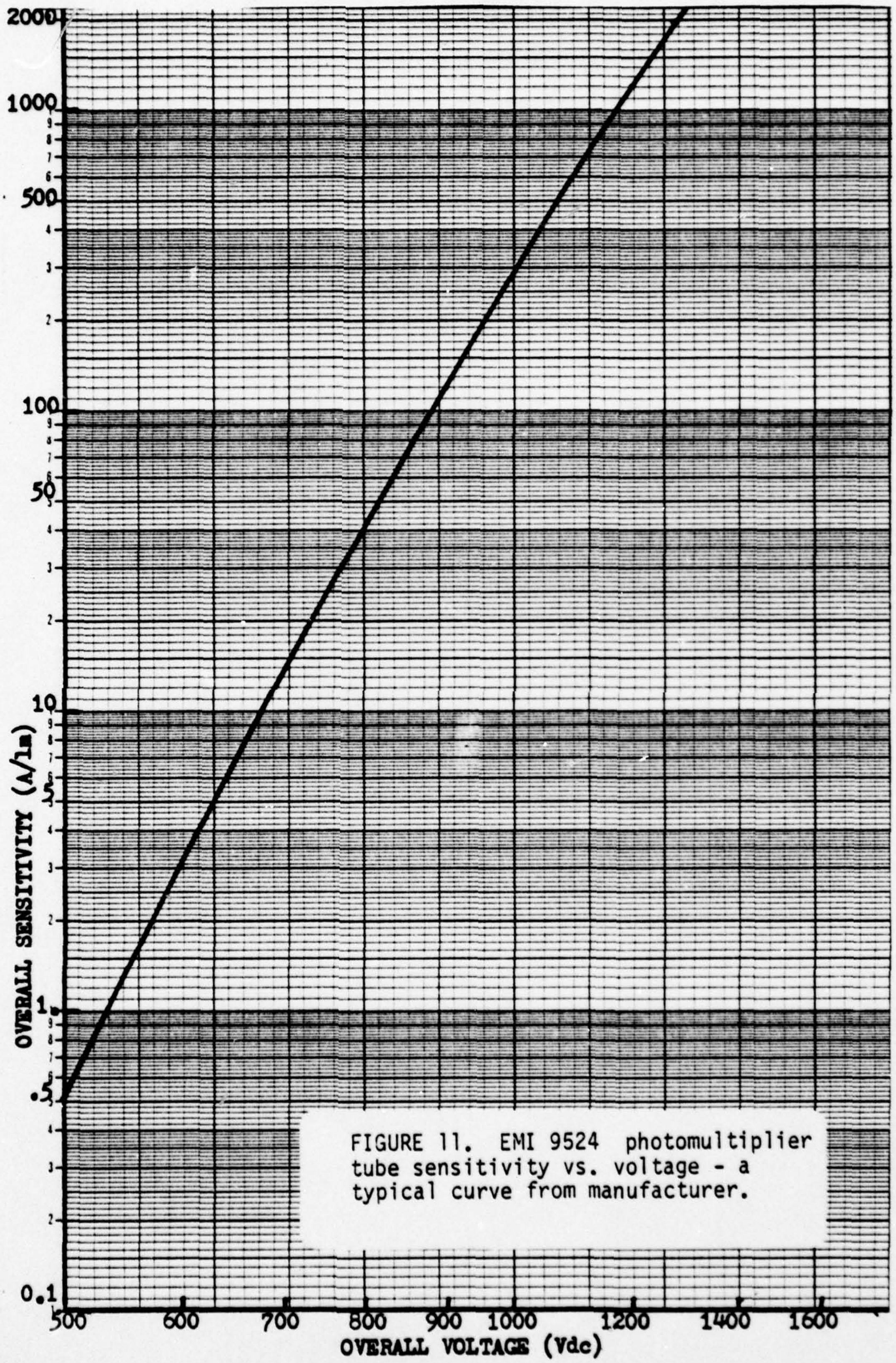


FIGURE 11. EMI 9524 photomultiplier tube sensitivity vs. voltage - a typical curve from manufacturer.

is inadvertently exposed at high light level, the gain of the tube is automatically reduced to prevent damage; 2) The stability with time of the PM tube gain is improved, as the anode current is maintained at a low constant value; and 3) the dynamic range of light flux values which can be measured is accomplished with essentially the same qualtiy and stability, thus maintaining accuracy of measurement.

The output of the spectroirradiometer is thus an analogue voltage signal roughly proportional to the logarithm of the spectral irradiance within the instantaneous field of view of the collecting and filtering optics. A typical output signal is illustrated in Figure 12. Wavelength varies linearly along the time axis (abscissa) while the corresponding voltage representation related to the irradiance value is displayed on the ordinate.

3. Instrumentation

The output is directly displayed on a Hewlett-Packard (HP) Model 7100B, 10 inch strip chart recorder and simultaneously stored on a HP-3960 analogue tape recorder for subsequent data reduction. A HP-204C signal generator provides a highly stable 2048 Hz reference synchronization signal used as the reference sampling frequency during digitizing of the data.

An input voltage of +12 Vdc for the Burr-Brown Model 520/25 regulated power supply, a selectable low voltage (typically +3.0 Vdc) input to the spectral wedge filter motor, and the spectral irradiance output signal are carried by a 1-cm O.D., six-conductor, internally strengthened cable.

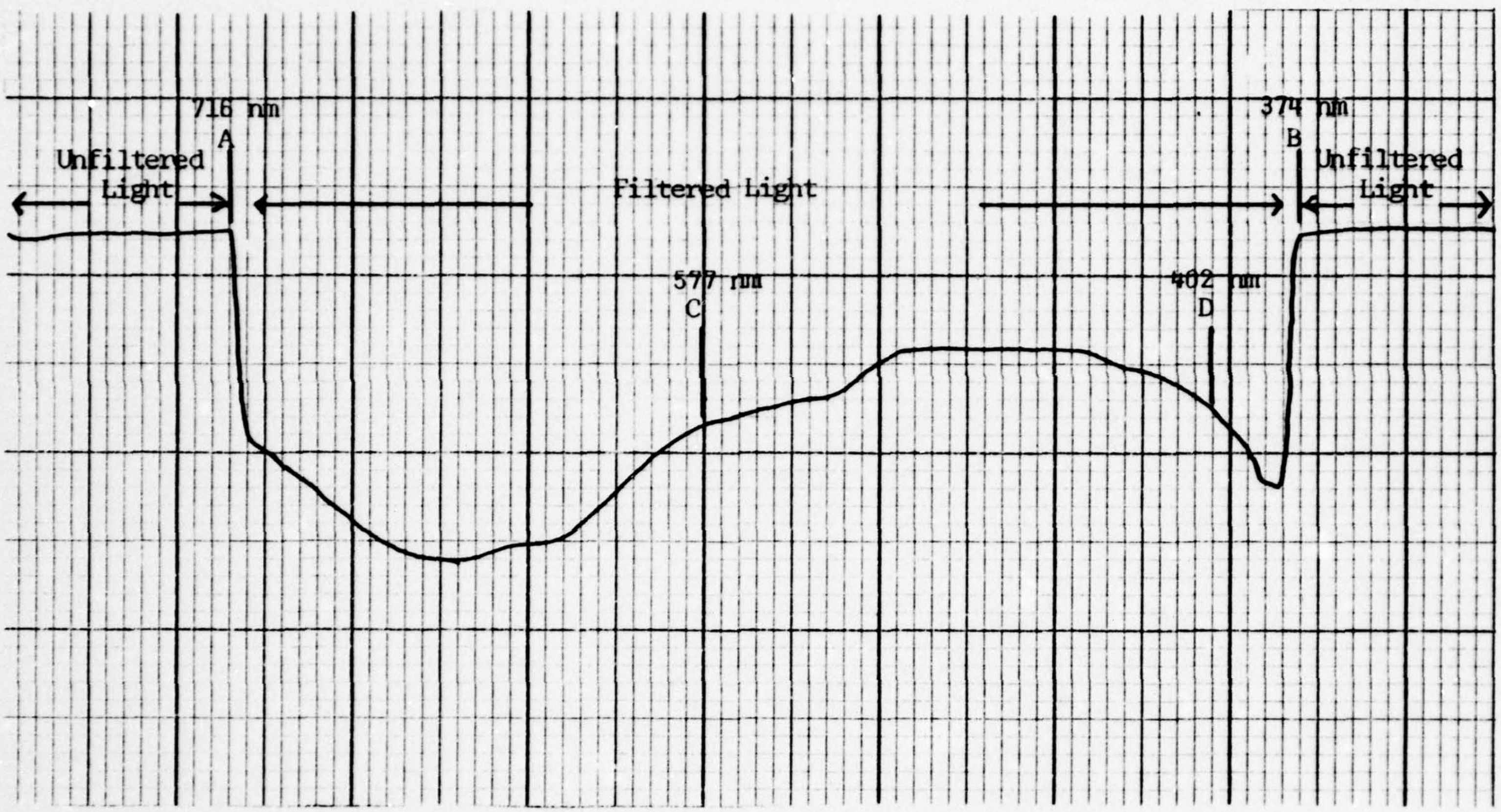


Figure 12. Typical output signal

A standard 75-cm instrumentation rack was used to house two regulated power supplies, a HP-680 strip chart recorder, a HP-204C reference oscillator, a Cimron DMC-45 digital multimeter/counter, and a specially constructed interface panel. The shipboard installation of the instrumentation package and the HP-3960 tape recorder is depicted in Figure 14.

The spectroirradiometer is suspended by a three-point bridle attached to the ship's hydrographic wire and is electrically connected to the shipboard instrument rack by an electrical cable which was manually deployed and married to the hydrographic wire. Vertical orientation and depth positioning of the unit was maintained by suspending a 100-pound lead weight below the unit on a second three-point bridle (Figure 15).

B. CALIBRATION

1. Absolute Spectral Irradiance

The absolute spectral irradiance calibration of the spectroirradiometer was accomplished using a Gamma Scientific Model 220 calibrated optical source, with a Model 220-1A radiance head as the standard lamp. The model 220-1A lamp has a light output of 100 $\pm$ 2 foot lamberts and color temperature of 2854 $\pm$ 50°K with $\pm$ 1.5% uniformity within the 7.62-cm diameter luminous surface. The calibration curve for the Model 220-1A standard lamp is shown in Figure 15. Radiance values less than 400 nm were not obtainable from the calibration curve.

To obtain a calibration standard at light levels higher than those of the Model 220-1A standard lamp, a General Electric (GE) iodine-cycle lamp (GE Type 1958) was used as a sub-standard. The GE lamp was positioned until the spectroirradiometer output voltage signal was identical to that of the 220-1A standard lamp. This output signal level and spectrum were then used as the reference for the GE lamp which was held at a constant current input in order to provide uniform radiation levels.

The spectroirradiometer was held fixed and the standard lamps displaced. At each position of the standard lamps the resultant spectrum of irradiance was recorded on the HP-5960 analog tape instrumentation and HP-7100B strip chart recorders. To ensure that an accurate representation of the standard lamp irradiance was measured, three spectra were monitored for each distance. The HP-5960 analog tapes were then digitized on a Vidar Model 6403D data acquisition system in IBM compatible format to allow determination of the absolute spectral irradiance values.

The value of radiance was determined for 98 discrete wavelength bands of 3.5 nm each from the standard lamp curve (Figure 15). The radiance value ($\mu W/cm^2/nm$) was then multiplied by the solid angle as viewed from the surface of the cosine collector. Each solid angle for the calibration was determined by dividing the effective area of the standard lamp luminous surface by the square of the distance between the lamp and the spectroirradiometer. The resultant of this

calculation gives the spectral irradiance values ($\mu W/cm^2/nm$) at the various calibration distances. The irradiance value was then correlated with the average spectroirradiometer output signal voltage in each wavelength band and an absolute spectral irradiance calibration curve determined for 77 wavelength bands.

The absolute calibration curves were determined by the following procedure:

(1) For each wavelength band of interest, denoted λ_i, i=1,2,........50 and at each distance from the lamp, the irradiance and corresponding voltage signal, denoted I_{ik} and V_{ik} respectively, were determined. The irradiances were previously computed from the known spectral distribution of the calibrated standard lamp. The corresponding voltage signals were determined by sampling the recorded data tape.
The end points of 374 nm and 716 nm (points A and B in Figure 12) were mathematically determined by computer to within .5% accuracy. Assuming that the spectral wedge filter rotated at a constant angular rate, equal interval sampling was used to determine V_{ik} for the 50 wavelength bands desired to calculate irradiances in the 402 nm to 577 nm regime (points C and D in Figure 12).

(2) Then, for each λ_i, ln (I_{ik}) was plotted as a function of V_{ik}. Points for which ln (I_{ik}) <

-9.21 were discarded as producing a response indistinguishable from noise. The remaining points were then fit with a cubic polynomial, using the weighted least squares fit with orthogonal polynomials (LEAST/EVAL) algorithms described on pages 43-51 of Shampine and Allen (1973). This algorithm choses the cubic polynomial, denoted $R_3(x)$, which minimizes:

$$\sum_k w_k [\ln (I_{ik}) - R_3(V_{ik})]^2 .$$

To avoid a result overly sensitive to low irradiance measurements, the weighting factor was chosen to be

$$w_k = e^{V_{ik}}.$$

Since V_{ik} was always negative, with its lowest values corresponding to the smallest irradiances, this weighting effectively weights the lower irradiance values less.

Figure 13 illustrates the calibration curve for the 487 nm wavelength band and is typical of the calibration curves determined in the above manner. The absolute spectral irradiance verified that spectral irradiance values as low as 1.0×10^{-4} μW/cm^2/nm can be measured by the spectroirradiometer over the spectrum of interest.

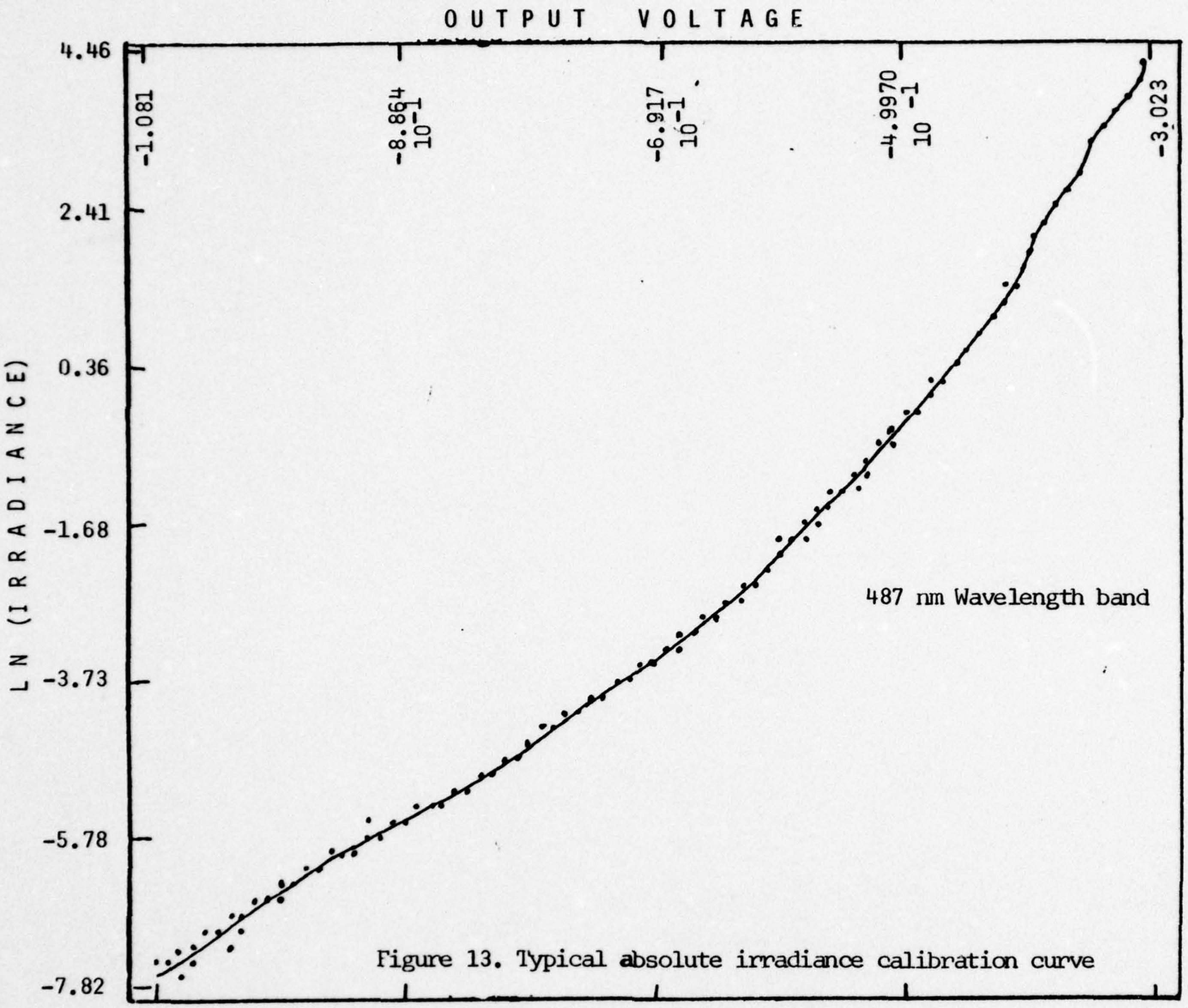


Figure 13. Typical absolute irradiance calibration curve

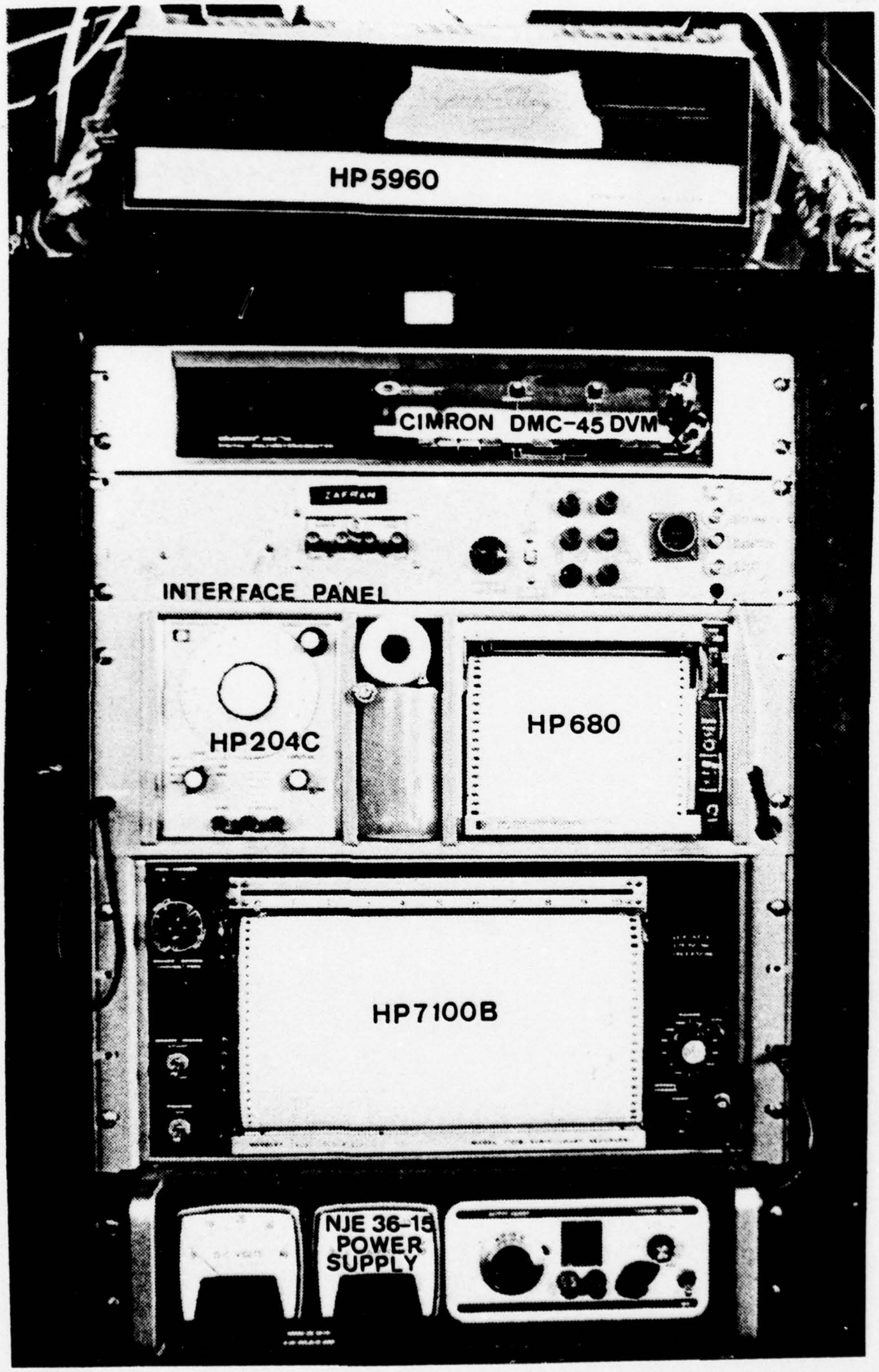


Figure 14. Instrumentation rack and tape recorder

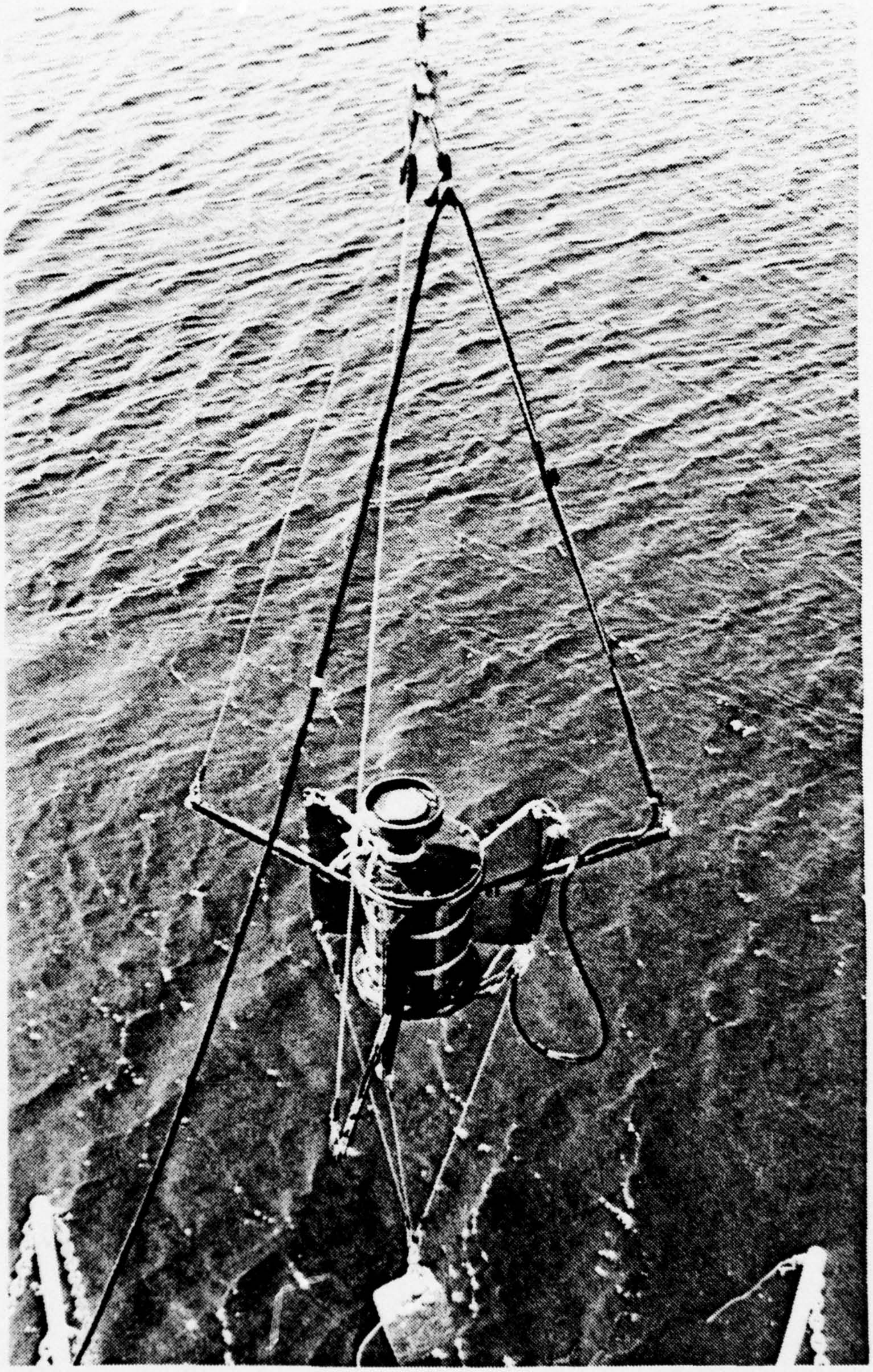


Figure 15. Spectroirradiometer Deployment

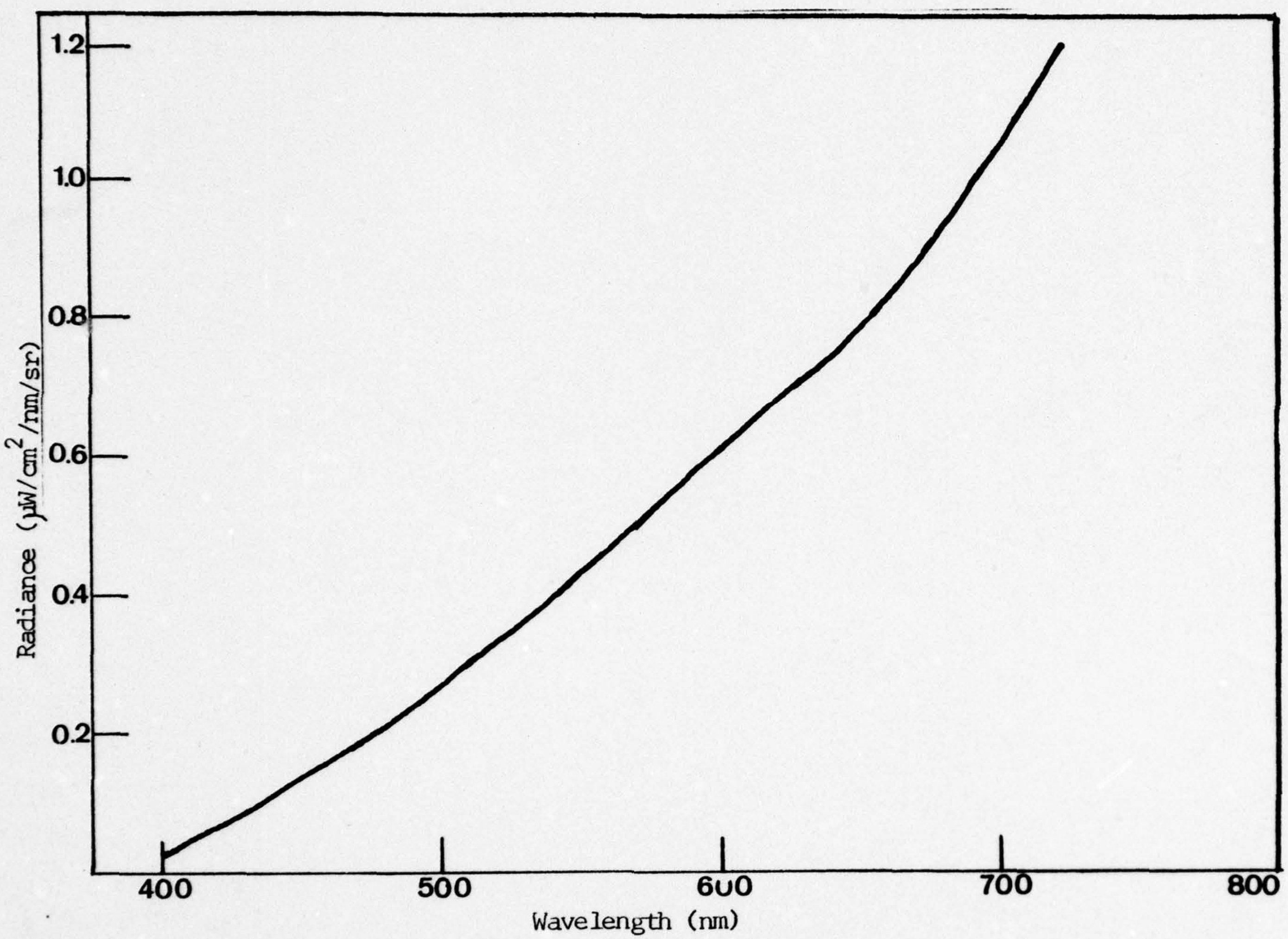


Figure 16. Standard lamp calibration curve

Since the absolute spectral irradiance calibration was accomplished in air, and the spectral irradiance measurements were made in seawater of average salinity 33.6-33.8%, a correction factor for the differences in indices of refraction between the calibration case (air and Plexiglas) and the *in-situ* case (seawater and Plexiglas) was required. The calculation for the correction factor (K) was based upon the Fresnel reflection formula for light at normal incidence to a surface separating two media having different indices of refractions.

K is computed in the following manner:

$$K = \frac{1-r_{pw}}{1-r_{pa}}$$

where:

$$r_{pw} = \left(\frac{n_p-n_w}{n_p+n_w}\right)^2$$

$$r_{pa} = \left(\frac{n_p-n_a}{n_p+n_a}\right)^2$$

and:

n_p = 1.49 = index of refraction of Plexiglas cosine collector

n_w = 1.33 = index of refraction of water, and

n_a = 1.00 = index of refraction of air

The *in-situ* irradiance values were corrected using the formula:

$$E^o_w = K\ E^o a$$

where:

E_w^o = Irradiance value at a given depth in seawater

E_a^o = Irradiance value at a given distance in air

K = 1.24 (as derived from above formula)

2. Spectral Wedge Filter

The spectral characteristics of the wedge filter as given by the manufacturer (Figure 9) were verified by calibrating the filter using narrow band interference filters to isolate the mercury spectral lines at 404.7, 435.8, 541.6, 577.0, and 690.7 nm. The end points of the filter were found to be 374 and 716 nm by linear extrapolation from the spectral data points given in Figure 9. The resultant transmission-wavelength calibration curve as a function of rotation angle of the filter is shown in Figure 17.

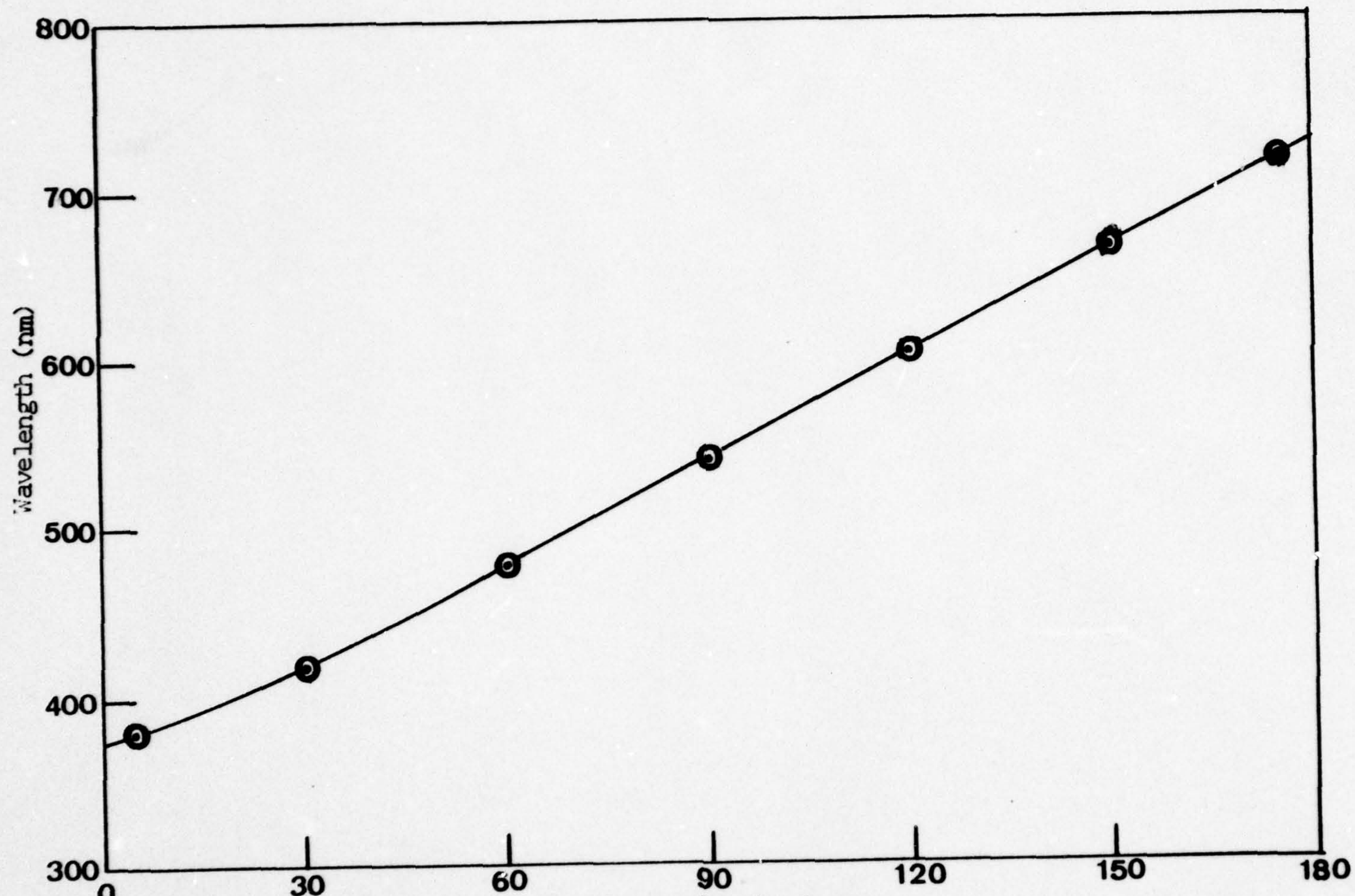


Figure 17. Spectral wedge filter calibration curve

III. COLLECTION OF DATA

A. LOCATION OF STATIONS

Between June and August 1976 spectral irradiance measurements were obtained by the author at a series of stations (Figure 1) in Monterey Bay utilizing the Naval Postgraduate School's oceanographic vessel, R/V *Acania*. Station positions were determined by the ship's radar and are listed in Appendix A with additional station data including time, sea and sky conditions, altitude and azimuth of the sun, Secchi depth, etc.

B. EXPERIMENTAL PROCEDURES

Sea and sky conditions can have significant influence upon underwater irradiance measurements. Tilt and vertical displacement of the instrument are highly dependent upon roll and drift of the ship. Shadows from the ship itself as well as from clouds also induce variations in the irradiance detected by a submerged underwater instrument. Obviously, the perturbations of the underwater light field as perceived by the instrument can be minimized or eliminated by obtaining data only under clear, sunny skies at times close to sun's zenith and under conditions of relatively calm sea and swell. In most cases data obtained in this study were taken within three hours of local noon, and the elapsed time sent at each depth was minimized in order to reduce effects

attributable to changes in sun angle or cloud conditions. The spectroirradiometer was suspended on an "A"-frame from the sunny side of the ship to minimize the effect of the ship's shadows.

At each station, the spectroirradiometer was lowered to the maximum extent of electrical cable available. The output signals were monitored on the HP-7100B strip chart recorder and simultaneously stored on the HP-3960 tape recorder. The time required to obtain one complete lowering of the instrument to 130 m is approximately one hour with 3-5 minutes at each depth. The station time given in Appendix A is the midtime of the measurement period.

Measurements of both no light and deck solar illumination conditions were also recorded with the device prior and subsequent to subsurface measurements. Secchi depth (30 m diameter disk) and mechanical bathythermograph data were obtained for each station.

A Weston Model 856 barrier-layer selenium photovoltric deck cell (Figure 18) with 10.93 cm^2 of effective collecting area was used to continuously monitor the solar radiation incident upon the sea surface. The photovoltric cell was gimbal-mounted and positioned in a shadow-free location on the ship. The output signal was monitored on a HP-680, 5-in strip chart recorder and stored on the HP-3960 tape recorder. This deck cell output can be used as a reference to normalize the subsurface irradiance values for calculating k.

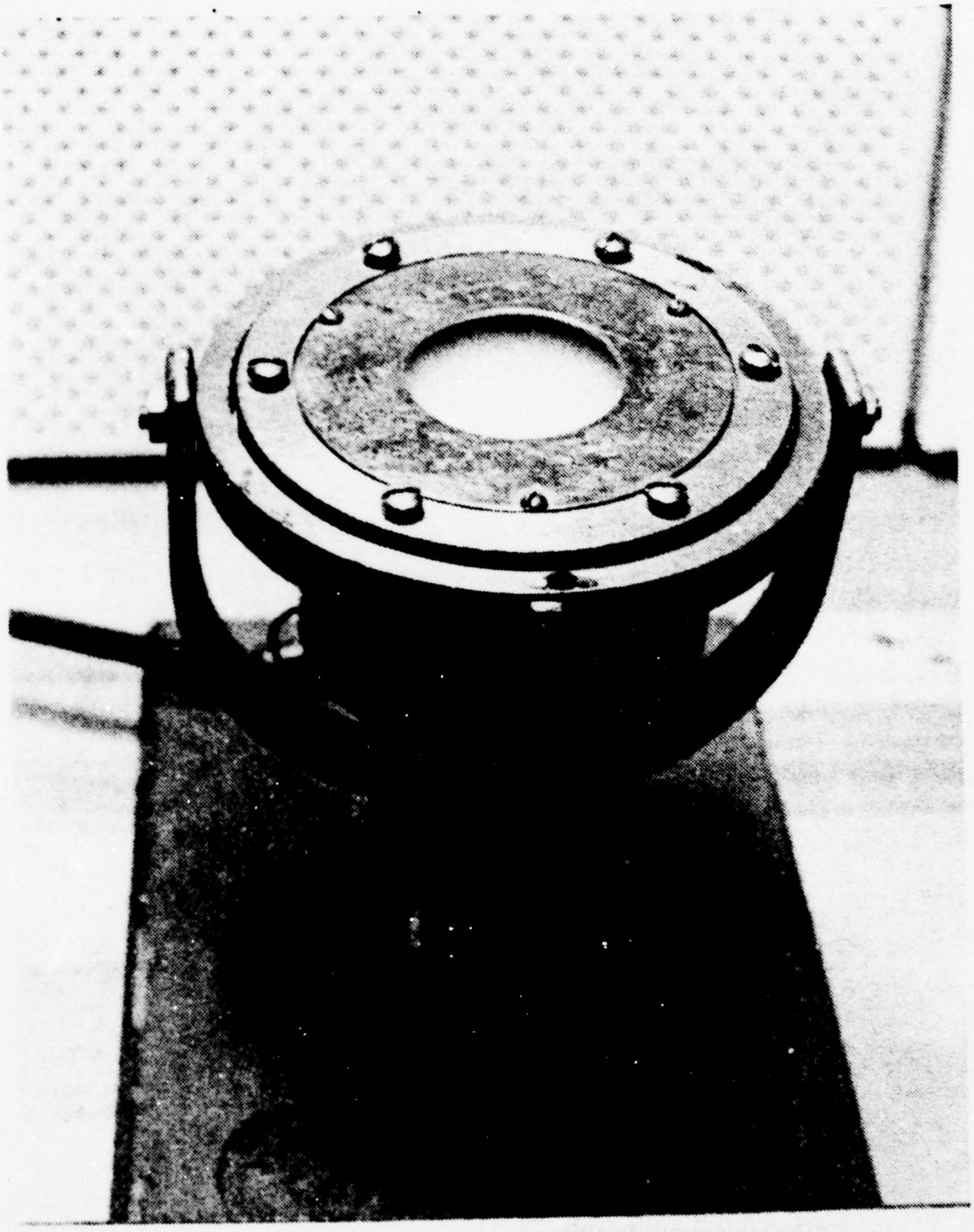


Figure 18. Deck cell in gimbal mounting

IV. ANALYSIS OF DATA

A. DATA REDUCTION

It is recognized that environmental factors, in particular inhomogeneities and temporal instabilities existing within the water mass structure, affect the characteristics of the distribution of spectral irradiance; however, with the exception of obvious discontinuities in the data, no attempt was made to identify or isolate such perturbations, and the effects of such perturbations are certainly present in the data.

To ensure that a representative irradiance spectrum was obtained three spectra for each depth were analyzed. As the spectral wedge filter revolves at a constant angular rate, wavelength intervals were determined from the ratio of the partial angular rotation to total angular rotation (Figure 17). Figure 19 illustrates a typical sequence of uncorrected data obtained at depth with unfiltered light (high light levels) followed by spectrally filtered light (lower light levels) in the 374 to 716 nm region. The 0° and 180° end points of the spectral wedge filter, shown as the sharp vertical lines, clearly delineate the end points of the irradiance spectrum. The filter drive motor operated at a constant voltage of +3.0 Vdc in order to produce a scan of the spectrum lasting 10 s between end points.

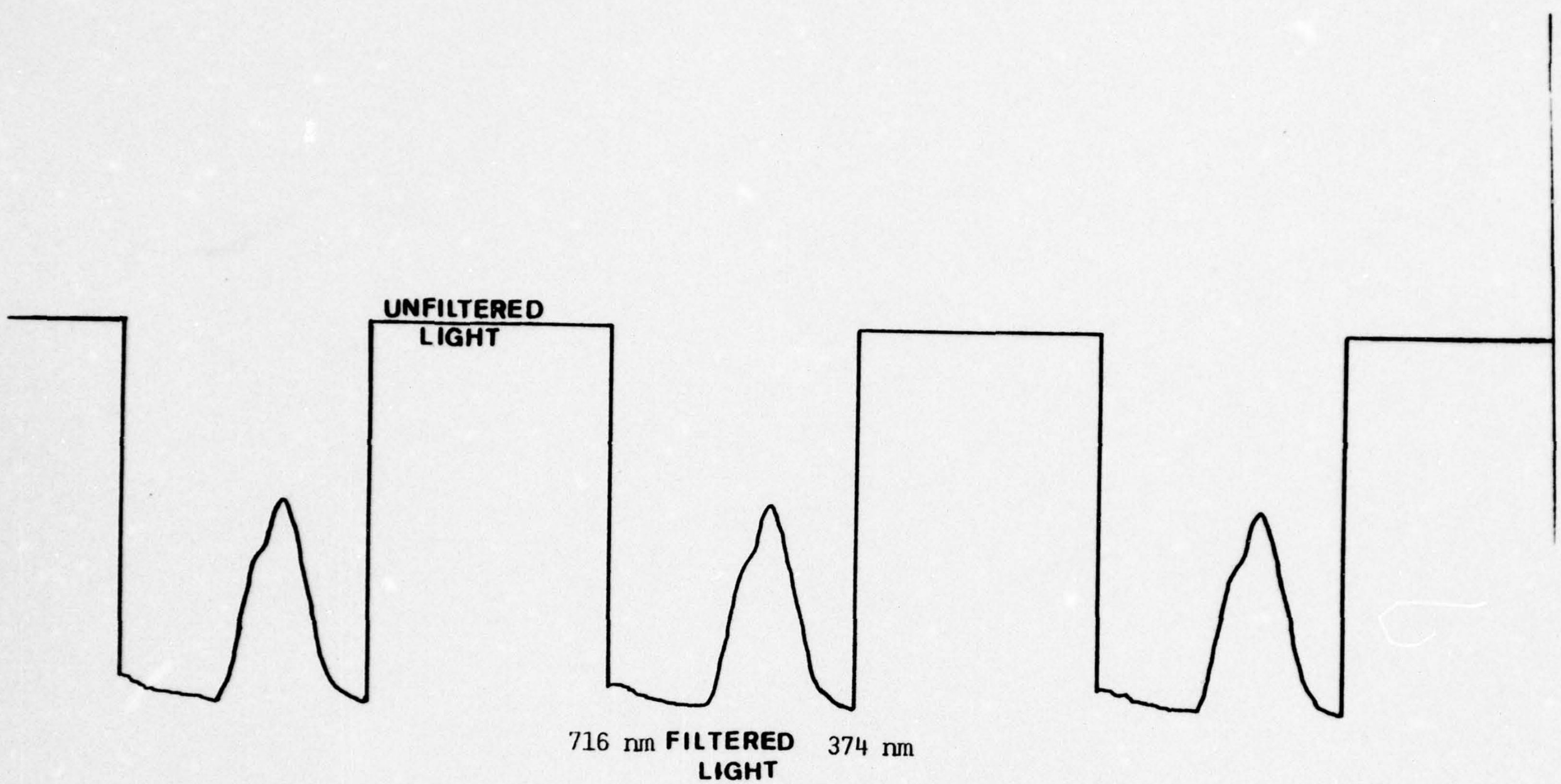


Figure 19. Output signal sequence

The irradiance data signal, a dc voltage level corresponding to the radiation incident on the Weston deck cell, a dc voltage corresponding to the depth of the device, and a 2048 Hz reference signal were recorded on the HP-3960 tape recorder in analog format and later digitized on a Vidar Model 6403D data acquisition system. The digitized tapes were then sampled on the NPS IBM 360/67 computer system utilizing the same scheme developed to determine the absolute calibration, and the representative data signal voltages were then converted to actual irradiances using the predetermined calibration curves for each wavelength band. Fifty increments of wavelength bands having an individual bandwidth of 3.5 nm were utilized in order to produce an overall spectrum of absolute irradiance from 402 to 577 nm. The determined irradiance values were then tabulated and used to produce computer generated plots for each depth at a particular station. Figure 20 illustrates the entire data collection and computer analysis scheme.

The spectral values of k, i.e. the "vertical extinction coefficient" or diffuse attenuation coefficient, were calculated from ratios of the downwelling irradiance at two depths, Z_1 and Z_2, using the formula:

$$k(\lambda, \frac{Z_1+Z_2}{2}) = (\frac{1}{Z_2-Z_1}) \ln (\frac{E(Z_1)}{E(Z_2)})$$

where Z is positive in the direction of increasing depth. The computed values of k are thus a function of wavelength and are given for the median depth between depths Z_1 and Z_2.

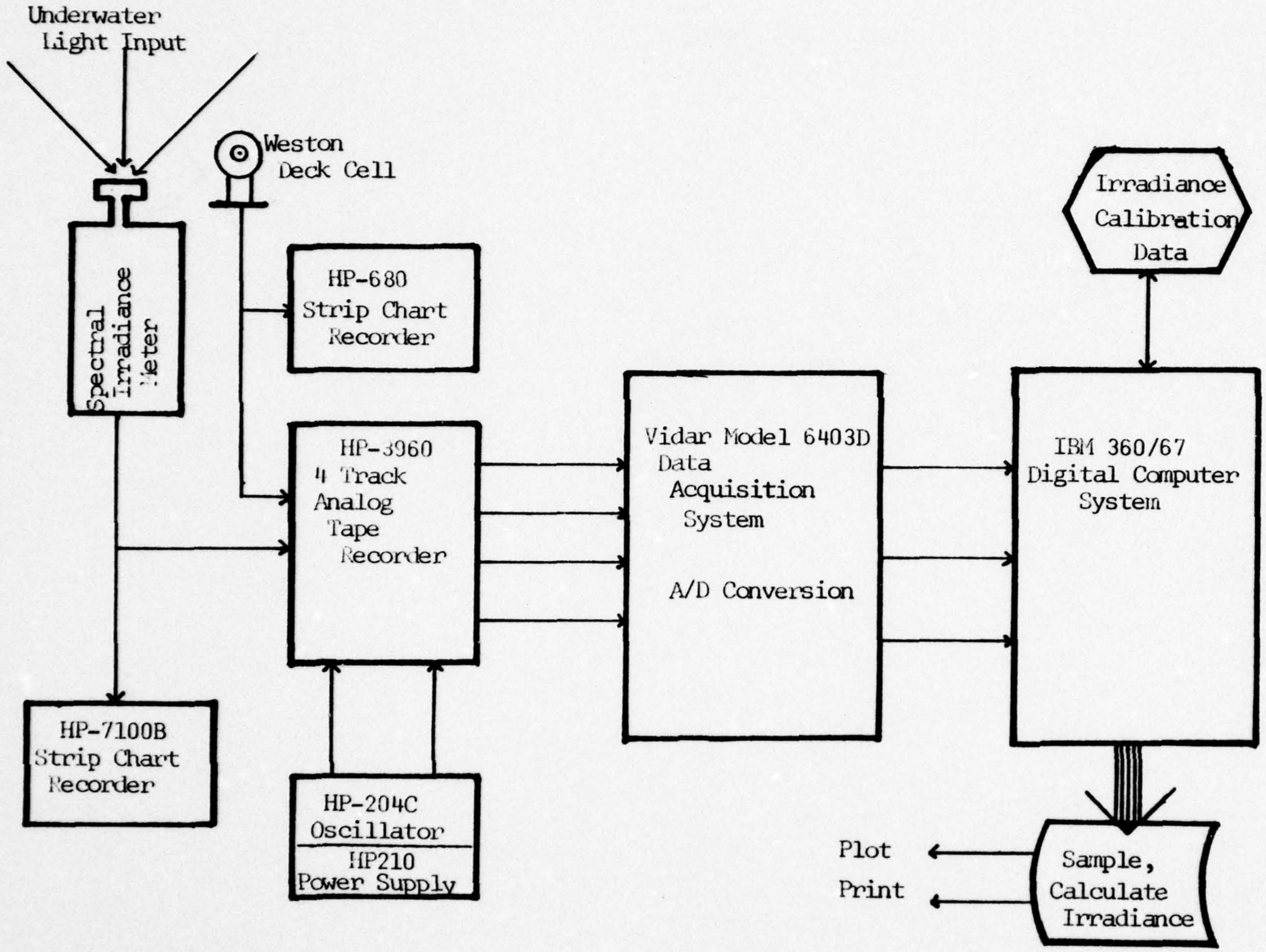


Figure 20. Data analysis scheme

B. RESULTS

Appendix B contains the derived spectral irradiance values tabulated for each depth at the four stations occupied in Monterey Bay. A composite plot of the spectral irradiance distribution with depth is also presented for each station.

Figures 21 through 25 contain the calculated values of k, the diffuse attenuation coefficient, for five midband wavelengths of 418, 453, 487, 523, and 558 nm. The thermal structure at the mid-station times (as obtained from mechanical BT data) is also presented (Figures 26 and 27).

Environmental factors affecting the measurement of downwelling spectral irradiance included the variations in sun zenith angle, presence of light fog, state of the sea, and inhomogeneities in the water mass. The data presented herein were obtained in relatively calm sea conditions and within three hours of local noon to minimize the effect from variations in the sun angle. Although light sea fog was present during the measurements for some of the stations, examination of the Weston deck cell measurements indicates that for all practical purposes the radiant energy incident upon the sea surface was relatively constant during the observation periods (an average of 30 minutes). With this assumption in mind, the data so obtained were not normalized and represent the actual downwelling spectral irradiances. However, it is recognized that small variations in the overall incident irradiance levels occurred from station to station. The data presented are tabulated to three decimal places for ease of computer calculations, although they are not accurate to more

than three significant figures. Irradiance values lower than 10^{-3} $\mu W/cm^2/nm$ were utilized as qualitative indicators but not for calculations.

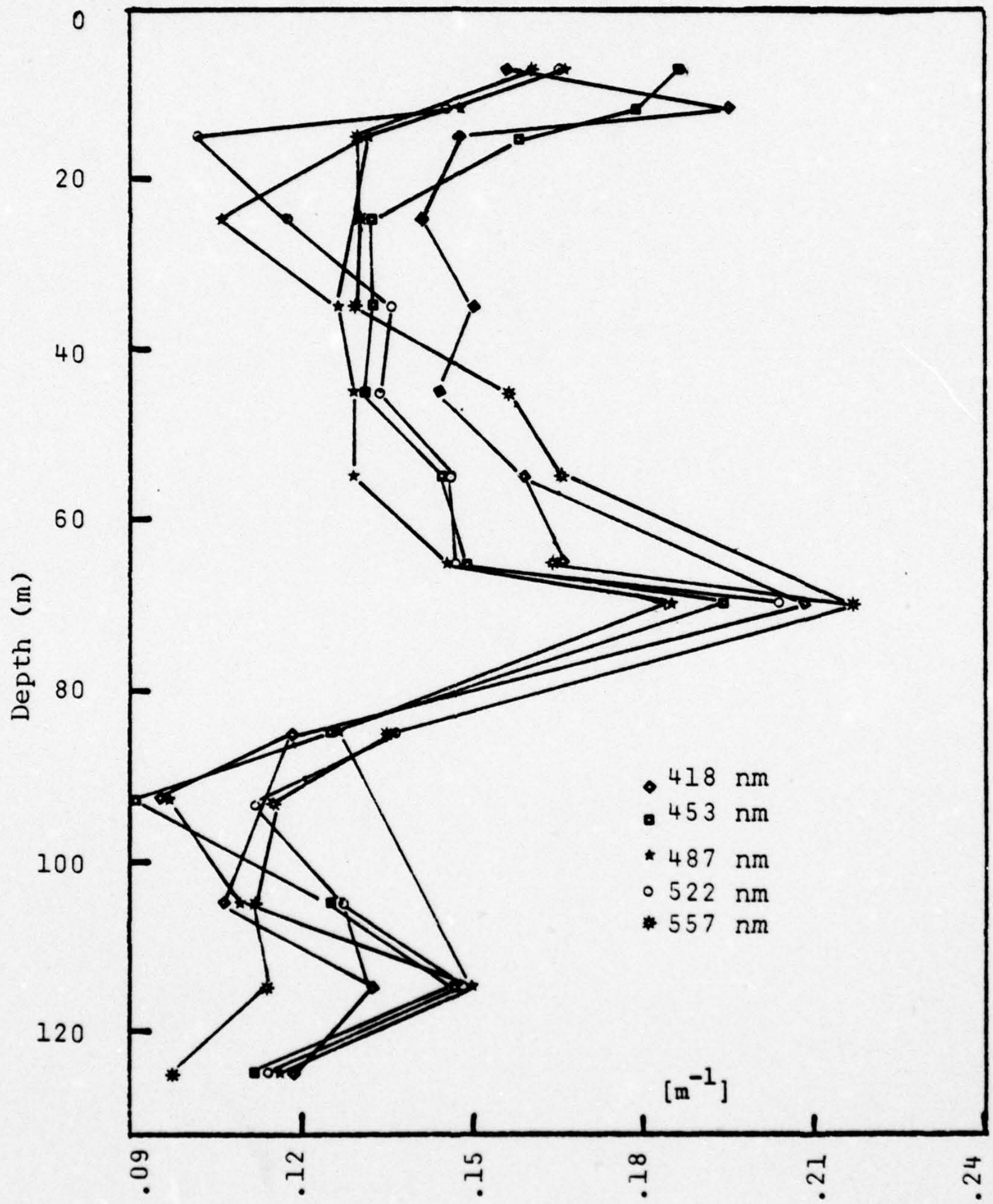


Figure 21. Diffuse Attenuation Coefficient Station A-7

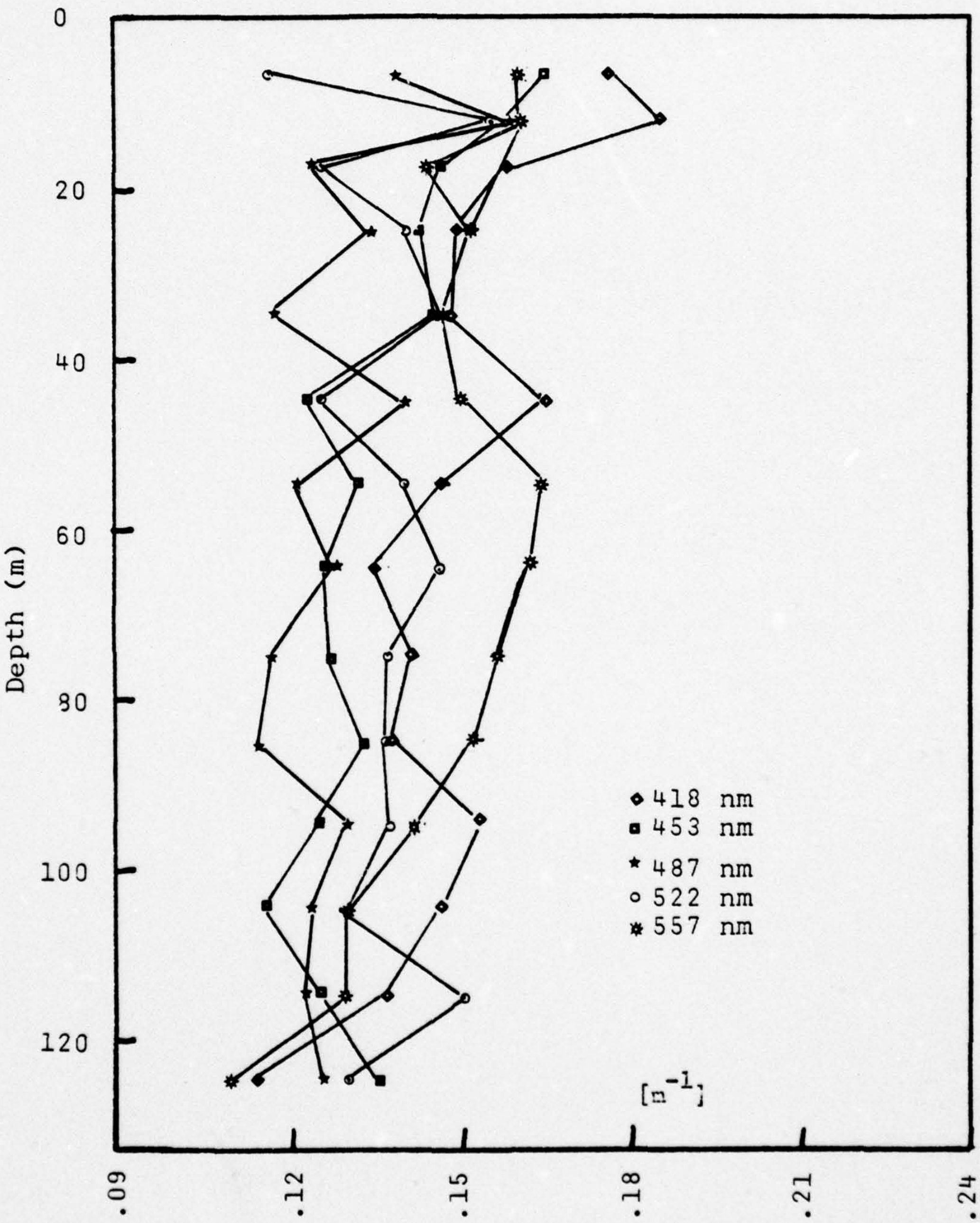


Figure 22. Diffuse Attenuation Coefficient Station A-6

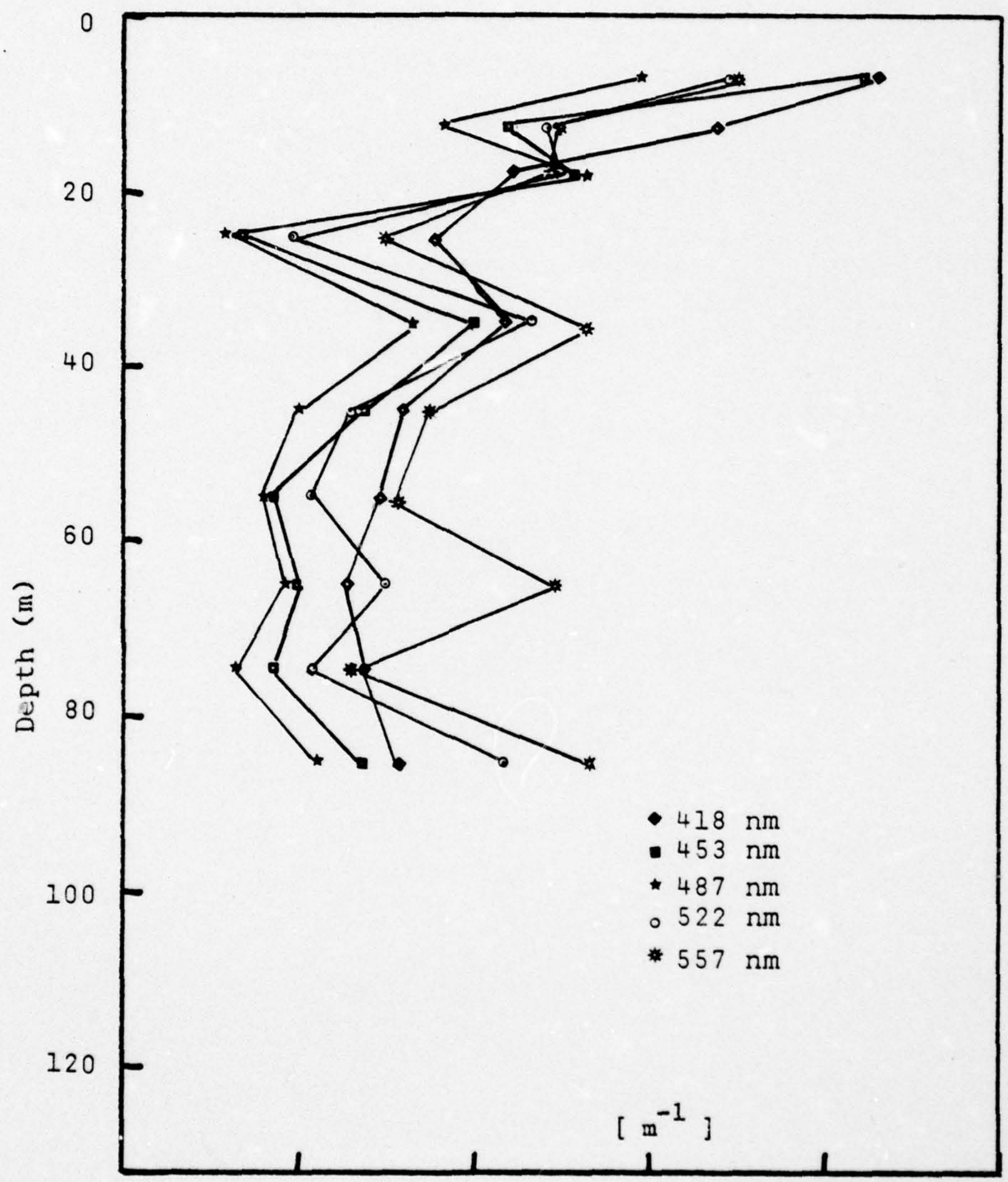


Figure 23. Diffuse Attenuation Coefficient Station A-5

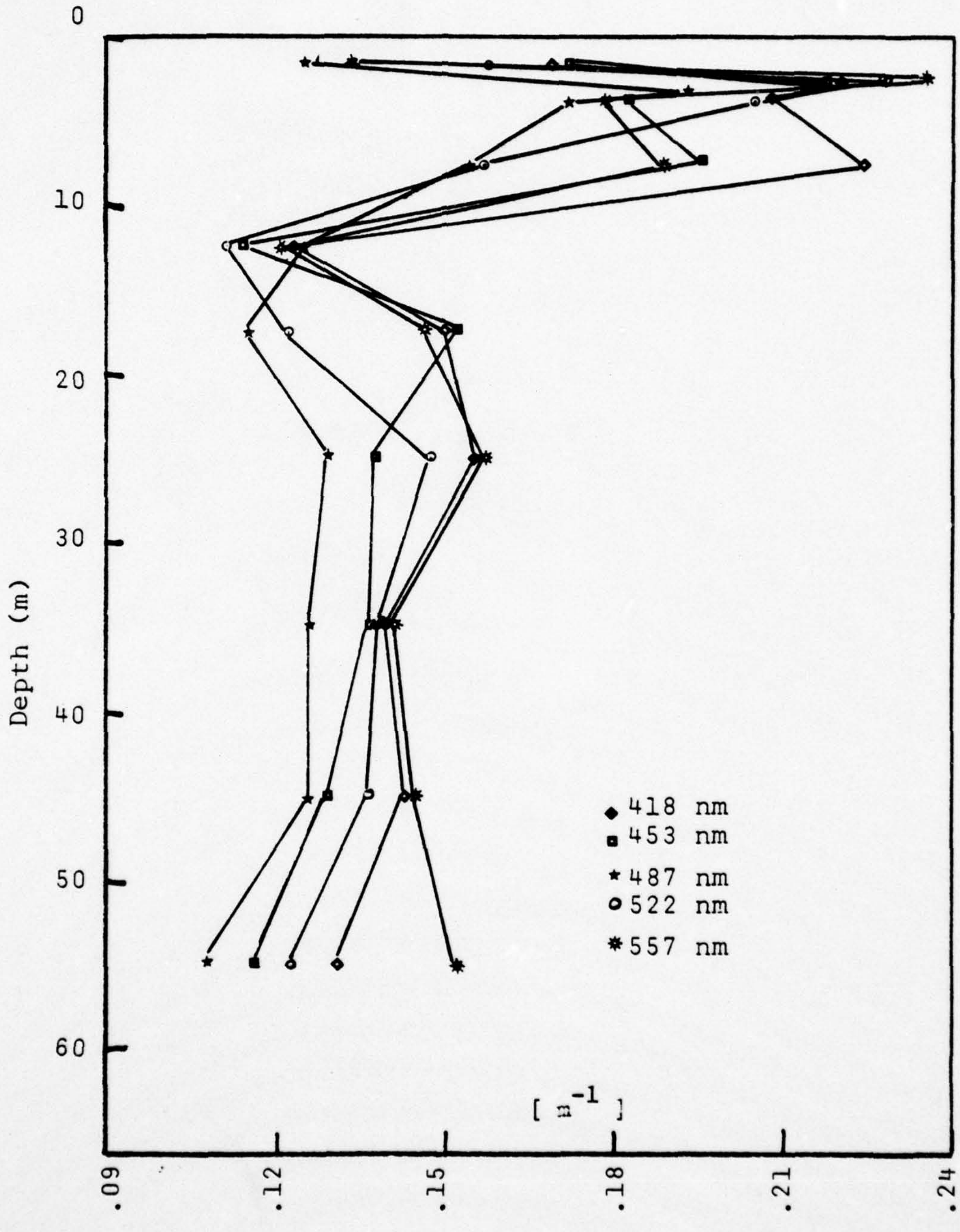


Figure 24. Diffuse Attenuation Coefficient Station A-1A

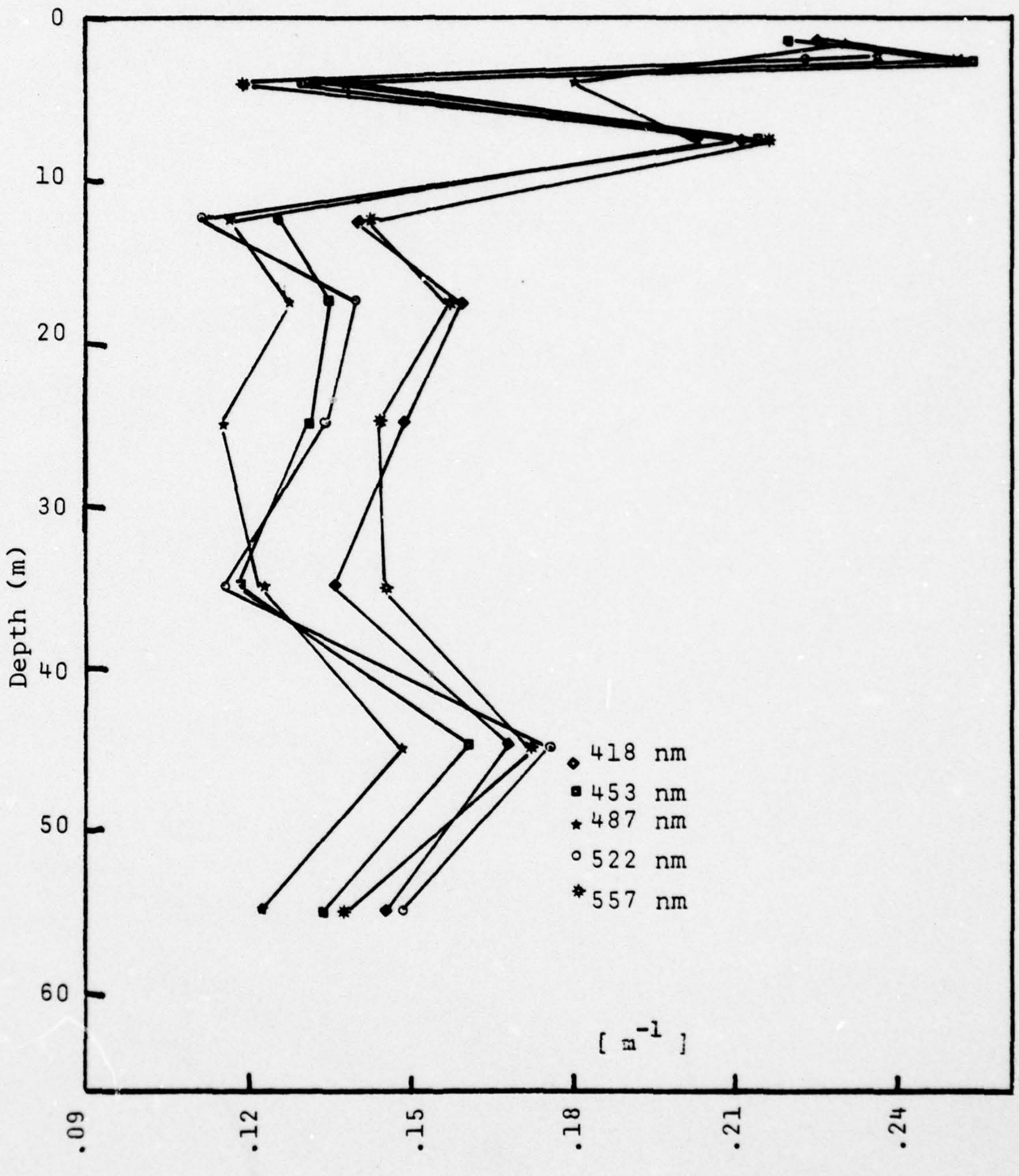
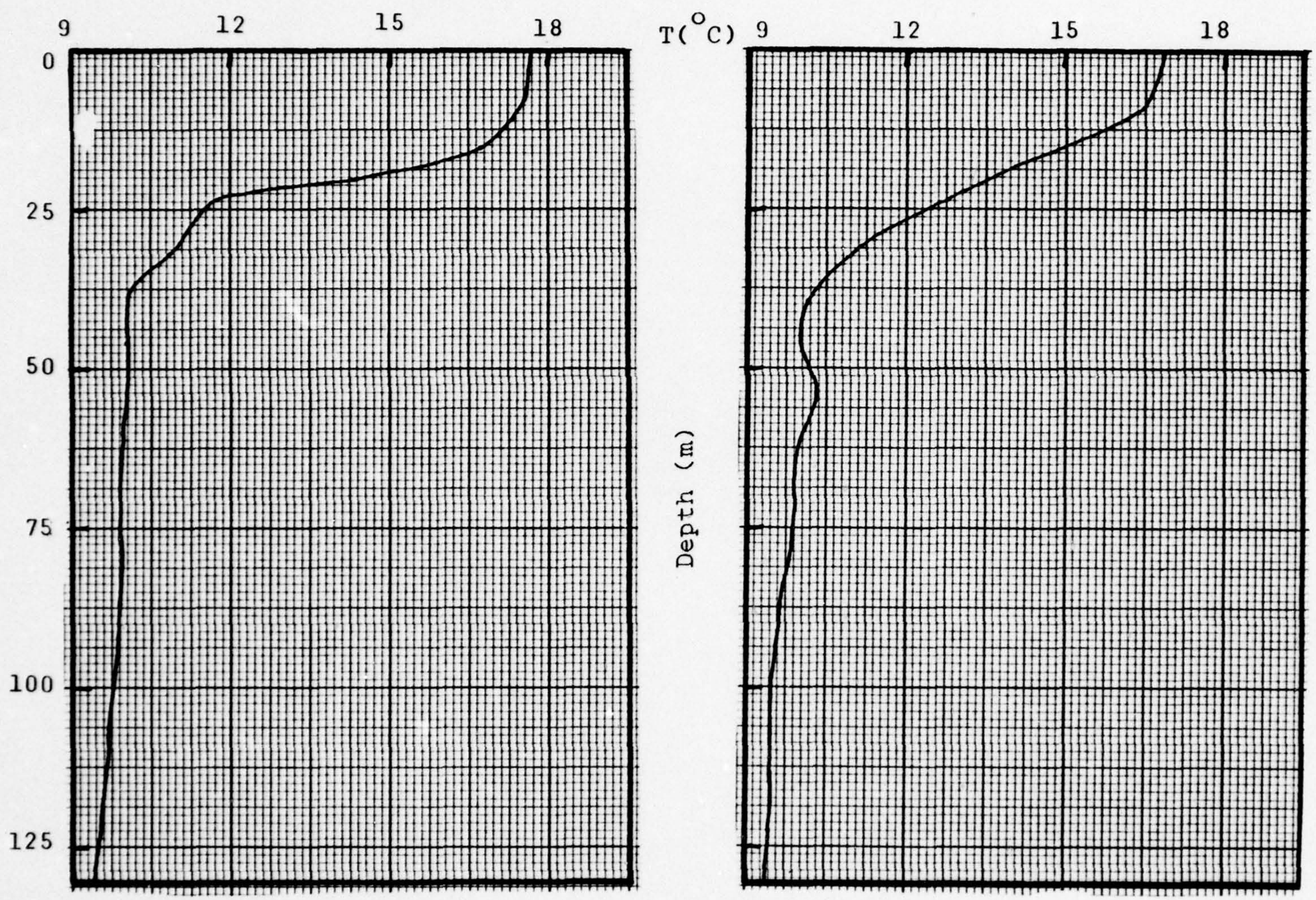


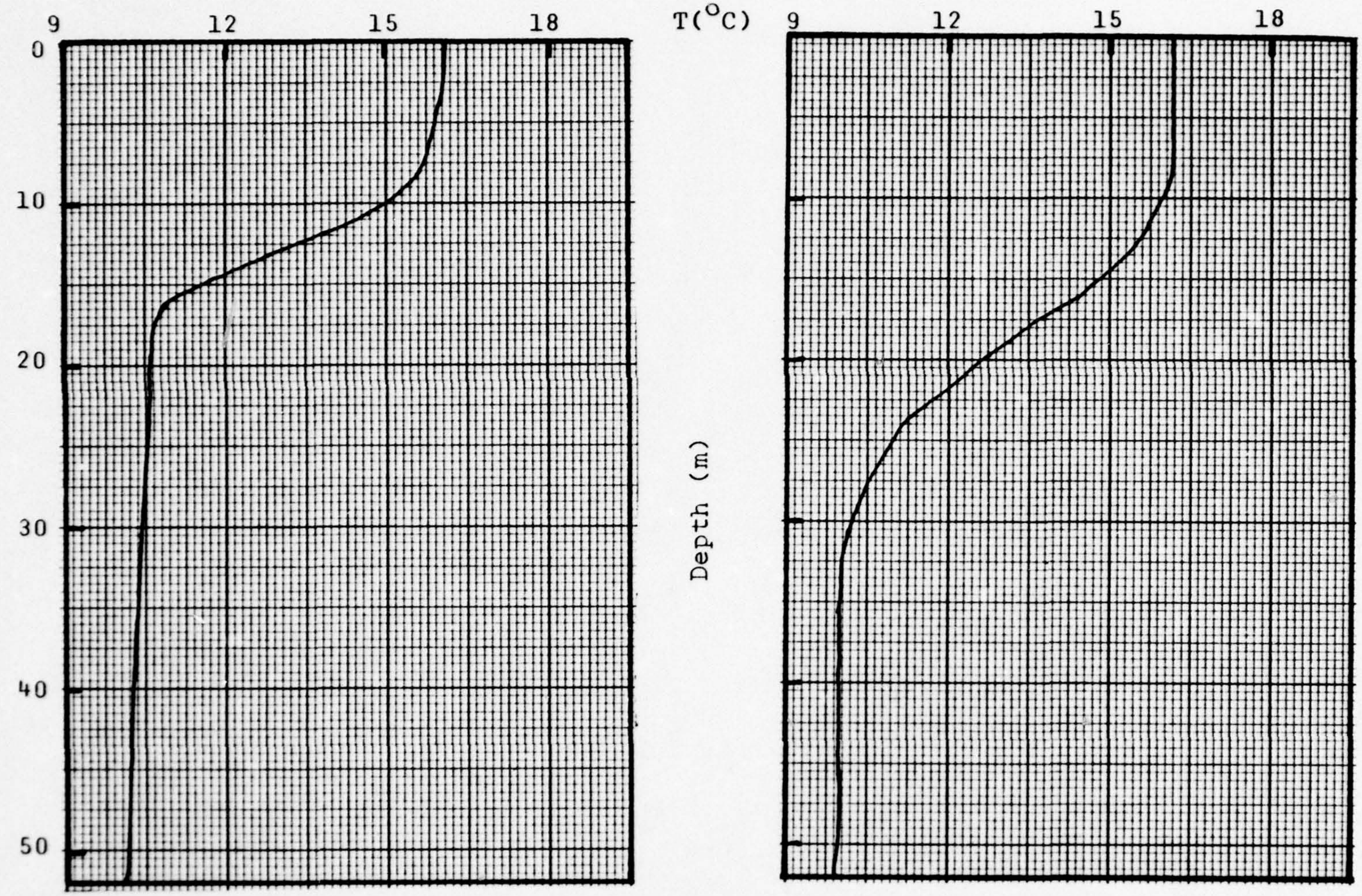
Figure 25. Diffuse Attenuation Coefficient Station A-1B



Station A-6 30 AUG 76 1330 PDT

Station A-5 30 AUG 76 1445 PDT

Figure 26. Bathythermograph Plots



Station A-1A 31 AUG 76 1030 PDT

Station A-1B 31 AUG 76 1245 PDT

Figure 27. Bathythermograph Plots

V. CONCLUSIONS

The values of spectral irradiance obtained seem to be representative of data obtained by other experimenters using comparable devices. The absolute values cannot be directly compared, as each observation is unique for the stations occupied, and there is no record of earlier spectral irradiance measurements taken in Monterey Bay. On a quantitative basis the data are comparable to downwelling irradiance values obtained from the Gulf of California by Tyler and Smith (1970) for May 1968; spectral irradiance values obtained from the Gulf of Panama and the Panama coastal area in the Caribbean Sea by Tyler (1970) during the SCOR Discoverer Expedition, May 1970; and spectral irradiance values obtained during the Cineca II expedition from coastal stations off Mauritania by Morel and Caloumenos (1973), April 1971.

A comparison of the spectral peaks of the observed irradiances reveals a shift toward the shorter wavelengths with depth as can be expected from the known optical properties of seawater. The shift is more apparent from examination of the tabulated values but is detectable when observing the composite plots of the irradiance distribution with depth (Appendix B). The spectral peaks were contained within a wavelength band of 484 to 502 nm and are consistent with known observations of coastal water masses.

The values of k were affected by the temporal instability of the water mass during the observation period, as approximately five minutes were required to return to an equivalent wavelength at the next lower depth. The plots of k versus depth reveal a variability which is not at all surprising in such a relatively shallow coastal environment.

The highest values of k occurred in the 557 nm wavelength band. For the shallowest station, A-1A/B, there are instances when the highest k values occurred in the 418 nm wavelength band.

The calculated values of k presented in Figures 21 through 25 are comparable to data obtained by Tyler and Smith (1970) in the Gulf of California, May 1968.

The analysis of the experimental data obtained using the Spectroirradiometer developed at NPS verifies that the device is capable of obtaining a measure of downwelling spectral irradiance in the 402 to 577 nm regime, and the spectral irradiance values can be utilized to calculate the diffuse attenuation coefficient, k, which may be used as an additional descriptor.

VI. RECOMMENDATIONS

The NPS Spectroirradiometer is serviceable as presently constructed, but the following modifications are recommended to improve data handling, calculation of absolute irradiances, and overall usability of the device for future studies:

(1) The shaft of the spectral wedge filter should be equipped with a cam actuated or optical device to signal the exact endpoints of the spectrum. The endpoints are now derived from mathematical comparisons of the average signal voltages.

(2) An absolute spectral recalibration should be accomplished utilizing a standard lamp having known spectral characteristics over the entire spectral wedge filter spectrum. This will enable measurements to be obtained on a wider spectrum than reported here.

(3) An accurate pressure transducer should be incorporated and utilized to record depths of the device during observations.

(4) The optical path should be equipped with additional filters to reduce bleedthrough of extraneous radiant energy.

(5) The data signal should be directly recorded on magnetic tape in a digitized format compatible with the NPS IBM 360/67 computer system. This would provide more accessible data measurements and reduce error during data analysis.

APPENDIX A

STATION DATA

STATION A-7

DATE	30 August 1976
LOCAL TIME	1145 PDT
LATITUDE	36.45.5N
LONGITUDE	121.53.5W
SEA	Calm
SWELL	325°/.5 m
WIND	000°/8 kt
SECCHI DEPTH	10.5 m
WATER DEPTH	135 m
SEA SURFACE TEMPERATURE	16.5°C
AVERAGE ALTITUDE OF THE SUN	61°
AVERAGE AZIMUTH OF THE SUN	216°
SKY CONDITIONS	Full Sun With Light Sea Fog

STATION A-6

DATE	30 August 1976
LOCAL TIME	1321 PDT
LATITUDE	36-47N
LONGITUDE	121-45.5W
SEA	330°/.2 m
SWELL	325°/1 m
WIND	300°/12 kt
SECCHI DEPTH	9.0 m
WATER DEPTH	320 m
SEA SURFACE TEMPERATURE	$17.6^{\circ}C$
AVERAGE ALTITUDE OF THE SUN	53°
AVERAGE AZIMUTH OF THE SUN	240°
SKY CONDITIONS	Full Sun No Clouds

STATION A-5

DATE	30 August 1976
LOCAL TIME	1442 PDT
LATITUDE	36-45.5N
LONGITUDE	121-54.5W
SEA	320°/.2 m
SWELL	325°/1 m
WIND	350°/11 kt
WATER DEPTH	95 m
SEA SURFACE TEMPERATURE	16.9°C
AVERAGE ALTITUDE OF THE SUN	41°
AVERAGE AZIMUTH OF THE SUN	258°
SKY CONDITIONS	Full Sun With Light Sea Fog

STATION A-1A

DATE -	31 August 1976
LOCAL TIME - - - - - - - - - - - - - - - - - - -	1030 PDT
LATITUDE -	36-39.5N
LONGITUDE - - - - - - - - - - - - - - - - - - -	121-54.5W
SEA -	Calm
SWELL -	330°/1 m
WIND -	350°/6 kt
SECCHI DEPTH - - - - - - - - - - - - - - - - - -	9.0 m
WATER DEPTH - - - - - - - - - - - - - - - - - -	75 m
SEA SURFACE TEMPERATURE - - - - - - - - - - -	$16.0^{\circ}C$
AVERAGE ALTITUDE OF THE SUN - - - - - - - -	63°
AVERAGE AZIMUTH OF THE SUN - - - - - - - - -	202°
SKY CONDITIONS - - - - - - - - - - - - - - - - -	Full Sun With Light Sea Fog

STATION A-1B

DATE -	31 August 1976
LOCAL TIME - - - - - - - - - - - - - - - - - -	1245 PDT
LATITUDE - - - - - - - - - - - - - - - - - - -	36-39.5N
LONGITUDE - - - - - - - - - - - - - - - - - -	121-54.5W
SEA -	320°/.2 m
SWELL -	330°/1.2 m
WIND -	350°/9 kt
SECCHI DEPTH - - - - - - - - - - - - - - - - -	9.0 m
WATER DEPTH - - - - - - - - - - - - - - - - -	75 m
SEA SURFACE TEMPERATURE - - - - - - - - - -	$16.2^{\circ}C$
AVERAGE ALTITUDE OF THE SUN - - - - - - - -	53°
AVERAGE AZIMUTH OF THE SUN - - - - - - - - -	210°
SKY CONDITIONS - - - - - - - - - - - - - - - -	Full Sun Clear of Clouds

APPENDIX B

SPECTRAL IRRADIANCE VALUES AND PLOTS

STATION A-7 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2/nm$)
WAVELENGTH (WL) IN NANOMETERS

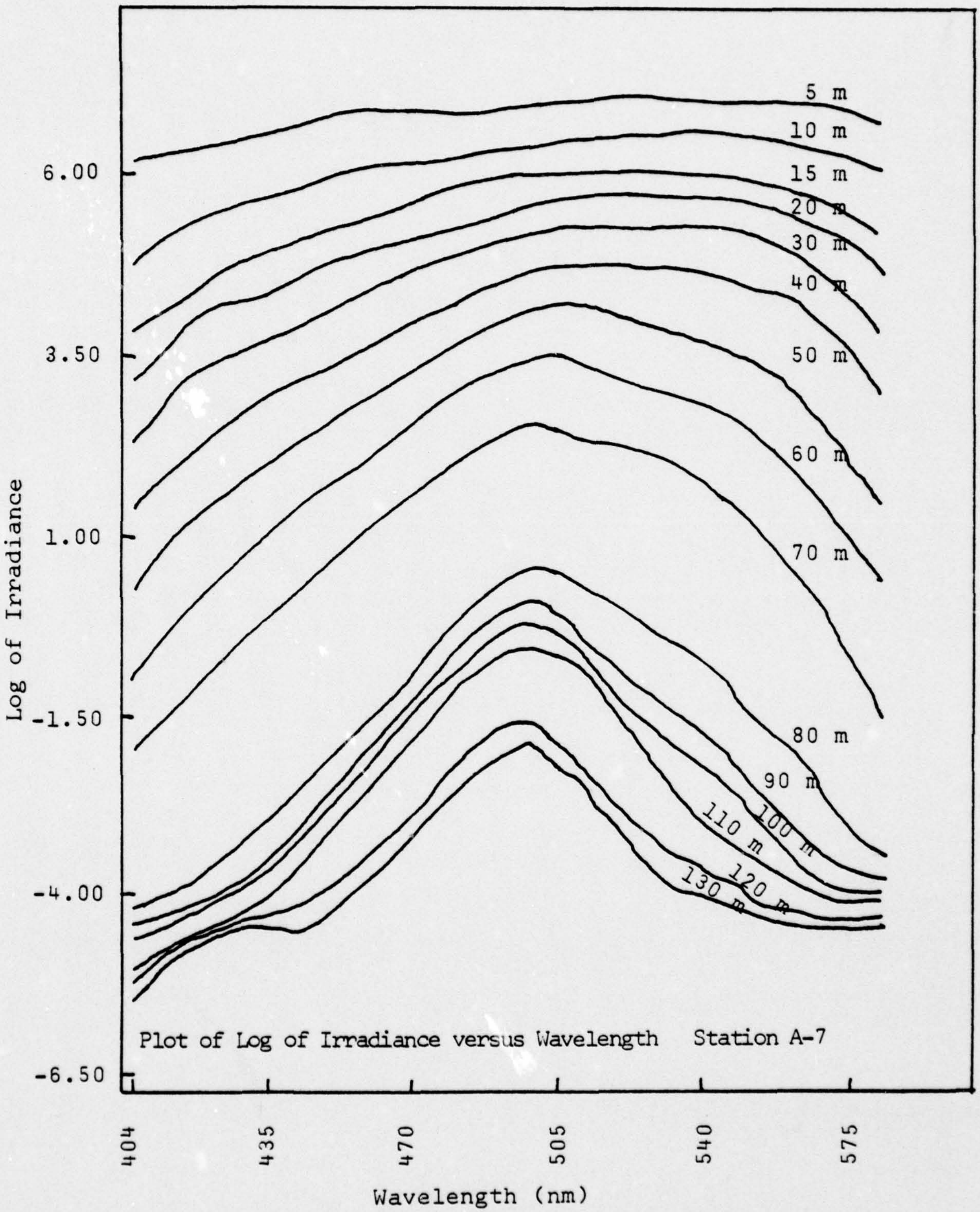
WL	5 m	10 m	15 m	20 m	30 m
404	20.922	9.397	4.148	2.235	1.081
407	26.385	12.766	4.108	2.419	1.332
411	41.815	17.771	7.001	3.290	2.002
414	37.635	16.982	6.513	3.409	1.908
418	44.951	24.761	8.842	5.441	2.326
421	68.774	20.789	8.666	5.440	2.610
425	45.836	19.796	9.401	5.693	2.452
428	46.443	22.919	11.781	6.268	3.0733
432	54.341	22.567	10.632	6.129	3.157
435	55.205	21.140	11.660	6.855	3.369
439	54.879	26.323	12.667	6.516	3.958
442	62.705	30.074	14.178	8.164	4.595
446	70.122	31.364	14.373	9.064	5.306
449	84.631	32.416	15.954	10.975	5.584
453	68.789	30.545	15.494	8.776	6.550
456	63.917	36.214	16.851	11.613	7.904
460	79.413	29.668	17.060	10.315	7.664
463	69.514	39.756	19.026	13.034	7.585
467	66.826	26.963	17.687	12.368	8.139
470	69.182	36.925	23.698	14.968	9.457
474	102.583	44.988	27.806	15.831	11.461
477	104.223	43.843	21.919	17.637	10.776
481	85.255	48.848	23.122	17.819	12.738
484	80.696	40.916	22.769	15.556	10.154
487	72.094	38.505	23.823	16.881	15.001
491	75.201	44.881	24.861	18.959	13.777
495	87.680	49.004	28.248	20.148	14.832
498	92.895	44.683	30.716	21.401	15.106
502	77.476	47.638	26.224	20.430	14.762
505	78.931	35.536	27.517	18.385	13.447
509	81.667	48.891	27.917	19.326	14.161
512	85.081	44.702	27.304	17.695	13.290
516	77.660	45.874	25.905	22.139	13.504
519	65.206	46.206	29.018	18.724	14.880
523	75.369	40.246	25.225	22.698	14.369
526	82.117	53.746	28.966	20.630	17.108
530	84.092	50.474	31.621	16.995	14.736
533	78.114	40.117	24.493	21.016	14.007
537	77.145	36.079	25.547	17.371	13.873
540	78.195	44.754	27.713	16.327	11.612
543	76.020	39.546	25.458	13.751	12.824
547	71.508	44.392	25.872	16.692	10.485
551	65.951	38.687	22.671	13.913	9.647
554	67.029	39.906	18.619	13.757	8.364
558	60.078	33.426	19.411	13.876	6.995
561	81.110	37.351	16.780	11.189	7.114
565	56.344	37.475	17.178	11.594	5.821
568	67.761	28.225	11.739	8.498	4.961
571	58.262	30.735	12.576	7.015	3.271
575	59.353	26.181	10.0880	4.748	2.505

STATION A-7 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	40 m	50 m	60 m	70 m	80 m
404	0.348	0.138	0.0413	0.0140	0.00098
407	0.472	0.216	0.0511	0.0152	0.00194
411	0.603	0.271	0.0737	0.0215	0.00155
414	0.691	0.299	0.0832	0.0245	0.00177
418	0.848	0.342	0.106	0.0303	0.00207
421	1.037	0.454	0.119	0.0353	0.00251
425	1.011	0.484	0.157	0.0404	0.00275
428	1.386	0.554	0.201	0.0524	0.00341
432	1.453	0.601	0.200	0.0621	0.00409
435	1.679	0.727	0.279	0.0791	0.00540
439	1.564	0.830	0.321	0.0968	0.00733
442	2.415	0.973	0.441	0.134	0.00970
446	2.809	1.306	0.526	0.150	0.0128
449	3.010	1.415	0.620	0.197	0.0157
453	3.273	1.644	0.651	0.243	0.0199
456	3.329	1.692	0.746	0.278	0.0250
460	3.884	2.445	0.994	0.321	0.0290
463	4.354	2.397	1.044	0.374	0.0329
467	4.829	2.441	1.169	0.382	0.0437
470	4.714	2.867	1.328	0.516	0.0528
474	6.167	3.502	1.345	0.590	0.0647
477	6.107	3.588	1.699	0.599	0.0733
481	6.842	3.744	1.750	0.743	0.0869
484	7.432	3.620	2.159	0.803	0.105
487	8.120	4.232	2.205	0.865	0.108
491	7.841	4.469	2.065	0.914	0.117
495	9.884	5.518	2.139	0.941	0.113
495	8.900	4.501	2.324	0.913	0.116
502	8.474	5.241	1.823	0.823	0.0918
505	7.109	4.305	1.970	0.695	0.0776
509	7.567	4.233	1.711	0.678	0.0622
512	7.382	3.514	1.638	0.601	0.0525
516	6.908	3.620	1.305	0.617	0.0442
519	7.640	3.705	1.505	0.554	0.0410
523	6.677	3.227	1.275	0.483	0.0356
526	8.878	3.059	1.285	0.451	0.0344
530	7.706	3.314	1.169	0.422	0.0304
533	7.062	2.942	1.064	0.409	0.0225
537	6.343	3.071	0.900	0.301	0.0186
540	5.689	2.310	0.770	0.279	0.0158
543	5.430	1.963	0.713	0.229	0.0126
547	5.185	1.918	0.674	0.212	0.00921
551	4.107	1.419	0.516	0.151	0.00774
554	3.757	1.498	0.489	0.134	0.00649
558	3.669	1.217	0.348	0.100	0.00498
561	2.817	1.025	0.330	0.0647	0.00363
565	2.390	0.768	0.197	0.0445	0.00330
568	1.655	0.546	0.138	0.0288	0.00243
571	1.204	0.321	0.0794	0.0196	0.00218
575	0.891	0.210	0.0518	0.0124	0.00196

STATION A-7 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	90 m	100 m	110 m	120 m	130 m
404	0.00073	0.00092	0.00073	0.00048	0.00043
407	0.00106	0.00077	0.00077	0.00068	0.00052
411	0.00097	0.00091	0.00078	0.00066	0.00061
414	0.00120	0.00102	0.00090	0.00084	0.00072
418	0.00128	0.00116	0.00084	0.00078	0.00073
421	0.00151	0.00123	0.00097	0.00069	0.00084
425	0.00161	0.00142	0.00111	0.00085	0.00085
428	0.00203	0.00179	0.00138	0.00092	0.00084
432	0.00249	0.00214	0.00151	0.00101	0.00083
435	0.00323	0.00283	0.00175	0.00096	0.00088
439	0.00447	0.00366	0.00220	0.00120	0.00094
442	0.00567	0.00485	0.00298	0.00140	0.00109
446	0.00755	0.00637	0.00369	0.00145	0.00119
449	0.00975	0.00826	0.00509	0.00179	0.00139
453	0.0111	0.0109	0.00610	0.00235	0.00157
456	0.0143	0.0133	0.00814	0.00292	0.00194
460	0.0170	0.0159	0.00986	0.00357	0.00236
463	0.0208	0.0200	0.0122	0.00446	0.00303
467	0.0236	0.0224	0.0164	0.00572	0.00390
470	0.0301	0.0308	0.0192	0.00705	0.00492
474	0.0364	0.0361	0.0233	0.00879	0.00569
477	0.0421	0.0418	0.0274	0.0107	0.00716
481	0.0505	0.0492	0.0306	0.0117	0.00795
484	0.0529	0.0555	0.0346	0.0131	0.00862
487	0.0596	0.0544	0.0385	0.0142	0.00925
491	0.0676	0.0591	0.0375	0.0150	0.0100
495	0.0622	0.0496	0.0359	0.0137	0.00864
498	0.0619	0.0440	0.0294	0.0114	0.00760
502	0.0519	0.0340	0.0241	0.00925	0.00612
505	0.0403	0.0280	0.0167	0.00698	0.00433
509	0.0313	0.0191	0.0126	0.00455	0.00309
512	0.0231	0.0167	0.00889	0.00379	0.00238
516	0.0215	0.0141	0.00781	0.00297	0.00186
519	0.0182	0.0127	0.00670	0.00270	0.00174
523	0.0165	0.0108	0.00589	0.00226	0.00157
526	0.0155	0.00940	0.00501	0.00194	0.00137
530	0.0123	0.00794	0.00426	0.00170	0.00122
533	0.0101	0.00647	0.00355	0.00161	0.00122
537	0.00789	0.00490	0.00276	0.00142	0.00122
540	0.00663	0.00428	0.00232	0.00131	0.00103
543	0.00531	0.00298	0.00195	0.00127	0.00098
547	0.00414	0.00260	0.00161	0.00097	0.00081
551	0.00337	0.00217	0.00143	0.00089	0.00080
554	0.00272	0.00188	0.00135	0.00092	0.00080
558	0.00234	0.00162	0.00123	0.00082	0.00081
561	0.00186	0.00136	0.00108	0.00080	0.00079
565	0.00172	0.00141	0.00103	0.00087	0.00078
568	0.00159	0.00125	0.00097	0.00071	0.00084
571	0.00150	0.00108	0.00104	0.00079	0.00082
575	0.00145	0.00111	0.00110	0.00102	0.00102



5 m
10 m
15 m
20 m
30 m
40 m
50 m
60 m
70 m
80 m
90 m
100 m
110 m
120 m
130 m
6.00
3.50
1.00
-1.50
-4.00
-6.50
Log of Irradiance
404
435
470
505
540
575
Wavelength (nm)
Plot of Log of Irradiance versus Wavelength Station A-7

STATION A-6 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	1 m	5 m	10 m	15 m	20 m
404	56.911	34.909	9.914	4.533	1.803
407	65.329	35.591	14.383	5.716	2.431
411	108.217	58.344	21.019	9.352	3.811
414	83.037	43.682	18.550	8.802	3.885
418	107.678	50.014	22.001	8.112	4.582
421	146.577	53.183	21.173	8.360	4.622
425	112.797	46.585	21.399	8.948	4.688
428	77.153	46.150	22.650	11.619	6.772
432	118.466	62.334	28.306	8.618	5.972
435	111.318	50.066	27.278	9.918	7.720
439	106.203	66.027	32.746	11.990	7.318
442	177.759	65.340	40.860	12.915	9.137
446	119.286	63.470	38.092	16.037	11.214
449	99.418	66.731	41.676	15.818	12.682
453	93.134	69.893	37.673	21.207	13.199
456	149.965	91.898	39.127	18.992	15.219
460	128.450	80.157	51.326	19.786	15.431
463	114.003	81.810	54.081	21.725	18.664
467	124.776	76.201	49.303	22.645	16.874
470	166.919	101.746	55.753	24.581	18.610
474	166.329	118.179	57.828	31.963	18.332
477	187.415	119.312	56.692	31.726	22.562
481	124.575	101.133	50.955	27.837	24.543
484	94.293	110.726	50.808	32.035	19.052
487	84.396	89.985	59.530	32.901	24.767
491	143.194	97.011	48.090	36.998	19.716
495	190.410	105.673	65.751	41.334	33.818
498	192.443	80.145	71.208	42.470	24.954
502	178.041	125.811	51.256	40.710	27.472
505	93.290	106.051	55.653	32.582	24.225
509	167.939	99.487	46.605	34.688	24.550
512	226.721	68.702	50.601	31.208	23.589
516	119.343	69.785	50.433	36.096	21.652
519	108.173	79.035	57.269	31.806	23.795
523	113.721	78.491	62.976	36.283	27.105
526	135.882	83.705	64.576	46.094	23.684
530	204.577	97.151	68.016	45.348	26.351
533	134.845	82.524	62.461	33.448	26.796
537	167.056	96.241	52.645	36.288	20.949
540	197.041	119.416	69.542	33.898	22.598
543	171.601	136.541	59.416	30.906	18.008
547	140.178	108.586	51.219	28.919	18.896
551	155.144	87.210	50.600	33.608	14.951
554	120.368	75.299	41.064	23.386	15.044
558	118.156	77.853	43.065	23.723	14.987
561	101.065	62.138	40.316	27.041	13.327
565	161.449	56.840	40.112	20.106	12.718
568	118.173	68.970	35.823	18.098	10.424
571	86.204	64.042	31.962	12.805	6.830
575	106.608	77.444	28.757	10.262	6.027

STATION A-6 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

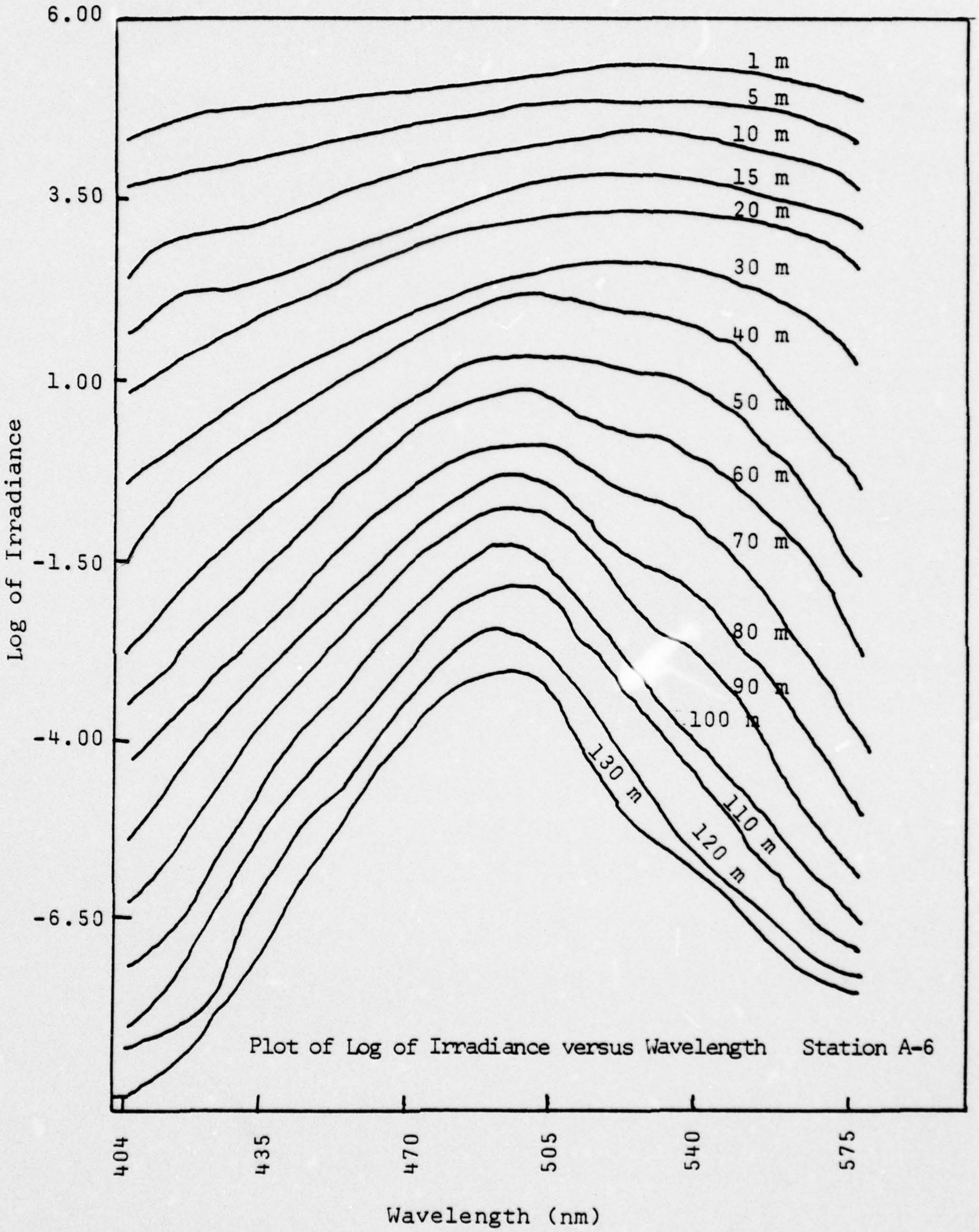
WL	30 m	40 m	50 m	60 m	70 m
404	0.714	0.234	0.0678	0.0271	0.0136
407	0.875	0.290	0.0883	0.0364	0.0157
411	1.183	0.441	0.116	0.0455	0.0218
414	1.334	0.510	0.154	0.0558	0.0273
418	1.697	0.638	0.181	0.0703	0.0329
421	1.825	0.738	0.229	0.0847	0.0409
425	1.795	0.754	0.231	0.0995	0.0468
428	2.405	0.960	0.337	0.133	0.0617
432	2.268	1.135	0.407	0.161	0.0787
435	2.810	1.257	0.452	0.197	0.101
439	3.691	1.571	0.553	0.264	0.142
442	3.936	1.776	0.765	0.370	0.184
446	4.372	2.289	0.857	0.445	0.221
449	4.525	3.010	0.944	0.521	0.275
453	5.235	2.819	1.078	0.622	0.305
456	6.836	3.208	1.302	0.690	0.416
460	6.092	3.578	1.765	0.854	0.440
463	6.981	4.449	1.807	0.986	0.539
467	7.712	5.022	1.961	0.977	0.651
470	9.098	5.335	2.232	1.119	0.687
474	9.366	5.670	2.833	1.532	0.785
477	9.807	6.411	3.085	1.629	0.851
481	10.654	6.123	3.106	1.675	0.977
484	10.673	6.923	3.672	1.792	1.057
487	11.550	7.286	3.296	1.964	1.037
491	12.168	7.505	3.380	1.909	1.063
495	14.873	8.384	4.265	1.917	1.047
498	13.615	8.535	3.693	2.026	1.035
502	12.055	7.171	3.665	1.526	0.970
505	12.245	6.757	3.308	1.443	0.740
509	12.109	6.187	2.716	1.262	0.667
512	10.288	5.605	2.724	1.014	0.529
516	12.734	5.436	2.563	1.128	0.543
519	13.358	5.224	2.548	1.029	0.523
523	10.260	5.692	2.447	0.950	0.427
526	12.400	5.145	2.065	0.868	0.381
530	9.836	5.723	2.305	0.799	0.338
533	11.148	4.585	1.888	0.732	0.315
537	8.480	4.355	1.567	0.676	0.276
540	9.229	3.619	1.298	0.533	0.201
543	7.832	3.470	1.126	0.465	0.172
547	6.573	3.543	1.143	0.354	0.142
551	6.097	2.726	0.941	0.326	0.109
554	5.833	2.191	0.843	0.252	0.0974
558	5.277	1.998	0.718	0.208	0.0614
561	4.488	1.861	0.521	0.160	0.0469
565	3.107	1.301	0.392	0.0961	0.0317
568	2.695	1.0450	0.248	0.0608	0.0211
571	1.954	0.649	0.144	0.0392	0.0132
575	1.380	0.410	0.0948	0.0262	0.00845

STATION A-6 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	80 m	90 m	100 m	110 m	120 m
404	0.00540	0.00238	0.00097	0.00049	0.00027
407	0.00573	0.00214	0.00089	0.00046	0.00032
411	0.00836	0.00345	0.00114	0.00041	0.00028
414	0.0102	0.00451	0.00167	0.00081	0.00036
418	0.0139	0.00612	0.00212	0.00081	0.00037
421	0.0169	0.00873	0.00316	0.00128	0.00059
425	0.0212	0.0108	0.00459	0.00184	0.00075
428	0.0275	0.0146	0.00631	0.00264	0.00122
432	0.0350	0.0194	0.00924	0.00418	0.00187
435	0.0453	0.0261	0.0121	0.00572	0.00290
439	0.0628	0.0341	0.0171	0.00835	0.00403
442	0.0832	0.0460	0.0231	0.0117	0.00645
446	0.103	0.0611	0.0296	0.0148	0.00798
449	0.144	0.0714	0.0375	0.0204	0.0109
453	0.165	0.0876	0.0421	0.0235	0.0144
456	0.220	0.123	0.0615	0.0325	0.0193
460	0.244	0.137	0.0796	0.0404	0.0217
463	0.292	0.166	0.0911	0.0472	0.0279
467	0.351	0.184	0.102	0.0613	0.0327
470	0.413	0.254	0.130	0.0730	0.0412
474	0.421	0.284	0.152	0.0874	0.0474
477	0.562	0.290	0.174	0.0992	0.0574
481	0.629	0.356	0.191	0.111	0.0618
484	0.704	0.355	0.235	0.121	0.0713
487	0.662	0.438	0.223	0.127	0.0737
491	0.652	0.383	0.226	0.130	0.0732
495	0.654	0.373	0.205	0.123	0.0636
498	0.585	0.341	0.184	0.0983	0.0547
502	0.533	0.240	0.137	0.0791	0.0426
505	0.396	0.226	0.104	0.0572	0.0268
509	0.309	0.173	0.0845	0.0447	0.0194
512	0.256	0.123	0.0584	0.0324	0.0141
516	0.257	0.107	0.0513	0.0262	0.0114
519	0.236	0.0922	0.0431	0.0221	0.00870
523	0.190	0.0875	0.0379	0.0195	0.00714
526	0.175	0.0749	0.0332	0.0156	0.00624
530	0.164	0.0610	0.0270	0.0130	0.00508
533	0.129	0.0533	0.0205	0.00984	0.00389
537	0.101	0.0393	0.0160	0.00731	0.00299
540	0.0744	0.0284	0.0124	0.00553	0.00225
543	0.0600	0.0197	0.00905	0.00379	0.00168
547	0.0452	0.0163	0.00611	0.00297	0.00137
551	0.0349	0.0131	0.00458	0.00215	0.00108
554	0.0274	0.00985	0.00371	0.00181	0.00092
558	0.0199	0.00703	0.00291	0.00146	0.00073
561	0.0135	0.00486	0.00200	0.00113	0.00072
565	0.00961	0.00324	0.00164	0.00096	0.00062
568	0.00600	0.00250	0.00128	0.00082	0.00056
571	0.00419	0.00186	0.00110	0.00073	0.00050
575	0.00315	0.00158	0.00094	0.00072	0.00045

STATION A-6 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	130 m
404	0.00016
407	0.00021
411	0.00017
414	0.00023
418	0.00025
421	0.00031
425	0.00042
428	0.00055
432	0.00065
435	0.00107
439	0.00166
442	0.00261
446	0.00353
449	0.00495
453	0.00662
456	0.00908
460	0.0112
463	0.0153
467	0.0182
470	0.0226
474	0.0265
477	0.0302
481	0.0376
484	0.0400
487	0.0402
491	0.0424
495	0.0343
498	0.0293
502	0.0214
595	0.0145
509	0.00978
512	0.00667
516	0.00547
519	0.00437
523	0.00366
526	0.00312
530	0.00243
533	0.00202
537	0.00168
540	0.00127
543	0.00106
547	0.00079
551	0.00068
554	0.00058
558	0.00053
561	0.00050
565	0.00058
568	0.00042
571	0.00039
575	0.00041



6.00
3.50
1.00
-1.50
-4.00
-6.50
Log of Irradiance
1 m
5 m
10 m
15 m
20 m
30 m
40 m
50 m
60 m
70 m
80 m
90 m
100 m
110 m
120 m
130 m
Plot of Log of Irradiance versus Wavelength Station A-6
404
435
470
505
540
575
Wavelength (nm)

STATION A-5 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

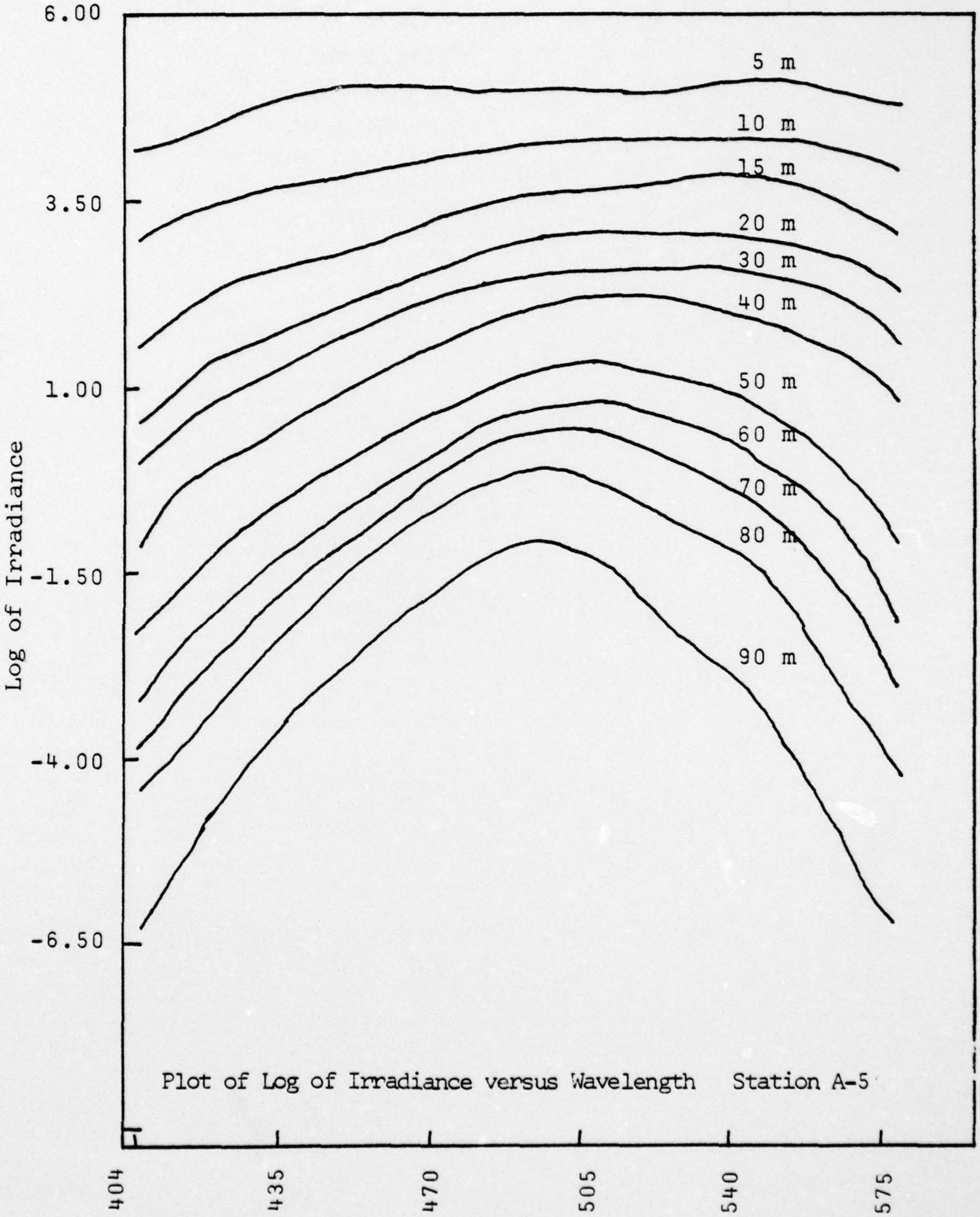
WL	1 m	5 m	10 m	15 m	20 m
404	78.977	21.210	5.849	2.083	0.926
407	103.342	18.401	6.337	2.209	1.170
411	209.388	33.300	10.230	3.060	1.550
414	152.801	23.995	9.690	3.693	1.754
418	200.673	37.757	9.538	4.074	2.337
421	227.257	32.476	11.815	4.494	2.432
425	228.069	34.926	10.768	4.833	2.222
428	292.586	41.472	12.144	5.078	3.102
432	224.978	37.639	12.601	5.687	2.912
435	247.146	35.857	11.820	5.696	3.322
439	245.788	36.528	15.262	6.789	4.046
442	324.160	46.327	18.023	7.832	4.120
446	297.725	50.197	17.117	8.004	5.072
449	345.989	56.190	20.842	9.163	5.656
453	367.053	51.664	17.978	10.456	5.530
456	281.529	52.141	22.430	11.582	6.733
460	317.697	50.866	22.801	11.726	6.401
463	275.598	63.449	20.610	13.601	8.679
467	346.823	63.001	24.386	15.115	6.999
470	367.971	68.549	25.142	15.253	8.297
474	406.063	66.843	32.638	16.512	9.987
477	402.116	71.164	32.786	19.992	10.265
481	315.067	63.263	26.209	15.401	7.217
484	300.001	72.217	29.388	19.264	10.342
487	305.148	64.711	30.911	21.628	11.136
491	361.457	63.042	30.148	20.050	10.452
495	436.429	91.699	33.319	22.205	12.816
498	328.033	85.058	36.617	20.399	13.689
502	431.745	78.213	35.167	19.634	12.556
505	267.844	62.973	27.128	20.087	11.278
509	265.518	61.893	30.614	21.861	12.044
512	250.306	68.494	39.652	17.171	12.568
516	178.129	75.780	35.372	21.712	12.075
519	191.859	72.537	47.594	21.632	12.970
523	134.083	90.703	37.927	20.270	10.649
526	159.412	77.791	43.370	19.431	12.065
530	158.926	87.940	47.911	25.224	12.017
533	125.416	71.313	32.597	19.188	12.034
537	140.171	81.256	40.875	20.603	12.042
540	138.065	76.230	36.535	22.664	12.958
543	119.090	69.992	41.936	17.280	10.817
547	143.840	67.464	33.794	17.880	10.348
551	112.412	53.680	27.100	15.234	10.343
554	114.559	58.165	26.914	14.385	8.198
558	113.440	61.347	25.430	13.658	7.390
561	133.602	65.127	26.022	11.132	7.584
565	92.014	55.691	23.970	10.878	6.318
568	108.140	50.357	17.534	9.176	4.625
571	117.213	40.079	16.195	7.909	3.220
575	119.522	39.908	12.920	5.944	2.631

STATION A-5 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	30 m	40 m	50 m	60 m	70 m
404	0.328	0.117	0.0537	0.0262	0.0139
407	0.466	0.185	0.0788	0.0347	0.0176
411	0.605	0.195	0.100	0.0438	0.0241
414	0.706	0.269	0.112	0.0555	0.0275
418	0.970	0.324	0.143	0.0692	0.0363
421	0.895	0.395	0.167	0.0799	0.0449
425	1.021	0.446	0.186	0.0906	0.0515
428	1.474	0.514	0.244	0.110	0.0662
432	1.450	0.570	0.274	0.137	0.0749
435	1.654	0.653	0.323	0.185	0.104
439	1.902	0.709	0.436	0.214	0.127
442	2.335	0.977	0.550	0.285	0.172
446	2.776	1.031	0.611	0.335	0.205
449	3.265	1.178	0.634	0.431	0.255
453	3.730	1.374	0.699	0.456	0.277
456	3.983	1.721	0.909	0.548	0.360
460	4.208	1.617	0.979	0.663	0.435
463	5.204	1.742	1.166	0.690	0.521
467	5.796	1.832	1.160	0.721	0.560
470	5.914	2.150	1.438	0.863	0.643
474	6.376	2.781	1.441	0.956	0.623
477	7.995	2.964	1.539	1.111	0.719
481	8.141	3.158	1.743	1.222	0.873
484	8.916	3.349	2.107	1.346	0.996
487	8.286	3.654	2.196	1.474	0.915
491	9.811	3.836	2.472	1.316	1.041
495	9.521	4.182	2.356	1.664	1.102
498	10.943	4.110	2.335	1.511	0.901
502	9.543	4.001	2.005	1.444	0.820
505	9.144	3.761	1.875	1.083	0.651
509	9.537	2.807	1.681	0.989	0.561
512	7.495	2.913	1.515	0.916	0.491
516	7.943	2.890	1.541	0.834	0.482
519	9.419	3.122	1.469	0.850	0.442
523	8.782	2.736	1.346	0.764	0.355
526	8.420	2.698	1.236	0.741	0.321
530	8.186	2.549	1.174	0.707	0.349
533	5.650	2.519	1.031	0.669	0.255
537	7.272	2.286	1.031	0.589	0.226
540	6.370	1.698	0.840	0.444	0.172
543	6.061	1.564	0.749	0.359	0.137
547	5.755	1.505	0.667	0.340	0.113
551	5.050	1.320	0.547	0.270	0.0879
554	4.345	1.200	0.506	0.200	0.0689
558	3.486	0.916	0.373	0.170	0.0497
561	3.300	0.803	0.282	0.121	0.0363
565	2.176	0.585	0.194	0.0885	0.0251
568	1.536	0.405	0.125	0.0570	0.0158
571	1.229	0.259	0.075	0.0319	0.0099
575	0.849	0.162	0.052	0.0235	0.0070

STATION A-5 30 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	80 m	90 m
404	0.00694	0.00276
407	0.00850	0.00354
411	0.0116	0.00481
414	0.0141	0.00638
418	0.0185	0.00853
421	0.0227	0.0105
425	0.0274	0.0136
428	0.0344	0.0173
432	0.0427	0.0226
435	0.0531	0.0279
439	0.0704	0.0365
442	0.0987	0.0522
446	0.116	0.0591
449	0.144	0.0787
453	0.178	0.0903
456	0.215	0.111
460	0.270	0.144
463	0.301	0.168
467	0.359	0.198
470	0.414	0.231
474	0.449	0.276
477	0.519	0.312
481	0.618	0.317
484	0.687	0.383
487	0.657	0.374
491	0.725	0.382
495	0.658	0.379
498	0.677	0.311
502	0.627	0.272
505	0.456	0.205
509	0.431	0.160
512	0.293	0.130
516	0.281	0.109
519	0.264	0.0930
523	0.227	0.0763
526	0.204	0.0743
530	0.184	0.0641
533	0.159	0.0486
537	0.122	0.0368
540	0.0988	0.0273
543	0.0749	0.0207
547	0.0574	0.0170
551	0.0507	0.0129
554	0.0379	0.00935
558	0.0261	0.00655
561	0.0201	0.00477
565	0.0134	0.00337
568	0.00854	0.00240
571	0.00573	0.00184
575	0.00395	0.00156



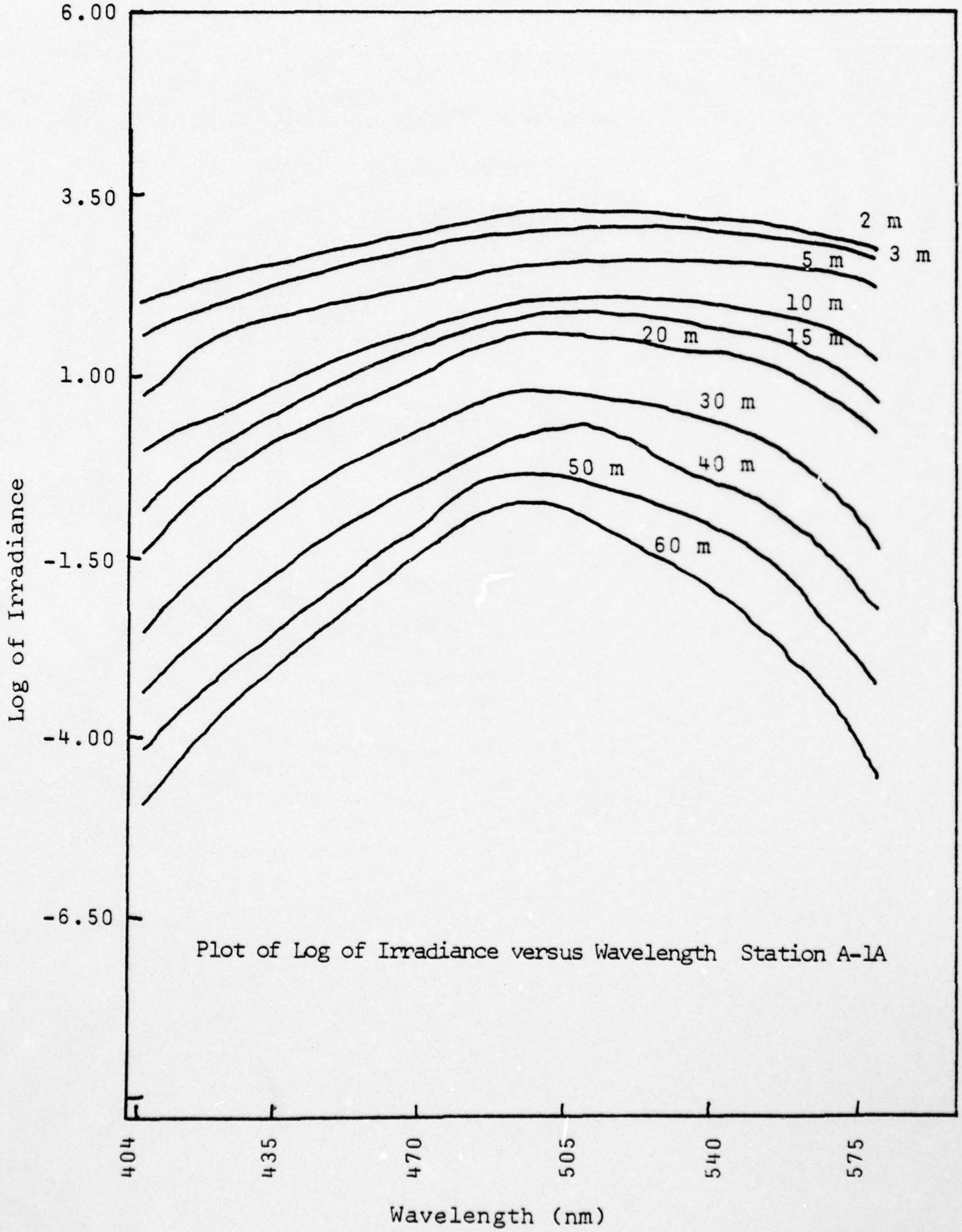
6.00
3.50
1.00
-1.50
-4.00
-6.50
Log of Irradiance
5 m
10 m
15 m
20 m
30 m
40 m
50 m
60 m
70 m
80 m
90 m
Plot of Log of Irradiance versus Wavelength Station A-5
404
435
470
505
540
575
Wavelength (nm)

STATION A-1A 31 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	2 m	3 m	5 m	10 m	15 m
404	5.919	3.714	1.988	0.686	0.505
407	5.780	5.220	2.671	0.926	0.685
411	8.333	7.568	4.323	1.311	0.911
414	11.250	5.959	3.666	1.305	0.987
418	9.866	7.189	4.850	1.573	1.201
421	11.416	10.133	5.098	1.662	1.281
425	9.610	9.146	5.124	1.893	1.390
428	13.613	11.335	6.825	2.278	1.709
432	11.394	9.450	6.910	2.086	1.750
435	11.225	9.036	6.855	2.359	1.810
439	11.230	11.446	7.630	2.631	2.015
442	14.984	12.740	7.399	3.151	2.591
446	16.220	12.826	8.327	3.085	2.638
449	16.232	13.116	10.218	3.842	2.837
453	15.069	12.194	8.986	3.811	3.464
456	15.429	14.253	9.829	4.060	3.041
460	20.006	17.107	9.769	4.139	3.654
463	15.638	15.304	10.343	4.645	3.803
467	15.880	14.628	10.596	4.047	4.009
470	16.058	18.106	11.560	5.335	4.387
474	19.077	17.128	12.237	4.525	5.190
477	19.359	20.633	13.596	4.988	5.488
481	17.143	17.143	13.335	5.541	5.209
484	21.590	17.687	11.460	5.854	6.016
487	18.761	18.358	10.907	6.399	4.783
491	18.438	15.967	10.762	5.694	5.336
495	19.977	21.393	12.642	6.315	5.864
498	21.280	19.777	12.965	6.216	5.909
502	17.298	19.858	10.228	5.682	5.962
505	18.284	16.340	10.698	6.079	5.367
509	16.686	18.028	11.916	6.250	4.668
512	16.174	16.351	9.516	5.703	4.755
516	18.343	14.021	10.557	5.410	4.762
519	17.288	20.459	11.262	5.058	4.899
523	20.384	15.389	10.593	6.078	5.098
526	19.542	18.726	11.741	5.665	4.808
530	22.924	15.756	11.075	5.041	5.439
533	16.334	15.768	10.278	4.874	4.733
537	20.096	17.277	11.330	4.946	4.376
540	16.236	20.027	12.572	5.338	4.801
543	18.107	15.240	10.731	5.167	4.037
547	16.692	15.212	11.231	5.198	3.493
551	14.364	14.871	10.157	5.025	3.195
554	16.551	15.084	9.089	4.164	3.124
558	16.681	13.059	9.687	3.782	2.914
561	16.001	15.627	9.138	4.243	2.664
565	15.829	13.781	10.030	3.258	2.009
568	12.902	11.920	8.863	2.860	1.834
571	13.520	10.814	8.393	2.541	1.261
575	13.382	11.550	6.649	2.223	0.977

STATION A-1A 31 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	20 m	30 m	40 m	50 m	60 m
404	0.282	0.087	0.0399	0.0175	0.00828
407	0.365	0.127	0.0535	0.0203	0.00943
411	0.493	0.154	0.0681	0.0287	0.0130
414	0.546	0.187	0.0793	0.0346	0.0165
418	0.718	0.220	0.0971	0.0395	0.0196
421	0.781	0.255	0.107	0.0481	0.0239
425	0.764	0.306	0.122	0.0518	0.0277
428	1.065	0.375	0.142	0.0649	0.0358
432	1.002	0.366	0.174	0.0814	0.0425
435	1.170	0.447	0.199	0.0957	0.0528
439	1.293	0.522	0.236	0.107	0.0676
442	1.567	0.572	0.322	0.147	0.0883
446	1.741	0.696	0.348	0.168	0.114
449	1.978	0.807	0.402	0.221	0.120
453	2.056	0.919	0.415	0.217	0.140
456	2.449	1.056	0.503	0.262	0.169
460	2.268	1.169	0.620	0.301	0.199
463	3.230	1.389	0.646	0.342	0.224
467	2.608	1.397	0.645	0.356	0.270
470	3.142	1.510	0.771	0.382	0.297
474	3.877	1.622	0.872	0.474	0.352
477	3.362	1.938	0.929	0.535	0.362
481	4.033	1.720	1.028	0.581	0.405
484	4.238	1.919	1.159	0.605	0.464
487	4.262	2.225	1.212	0.670	0.501
491	4.329	2.075	1.211	0.619	0.453
495	4.276	2.384	1.253	0.619	0.417
498	4.546	1.949	1.125	0.552	0.397
502	4.275	1.828	1.171	0.546	0.331
505	3.956	1.766	1.079	0.464	0.262
509	4.306	1.850	0.871	0.439	0.243
512	3.746	1.555	0.778	0.362	0.231
516	3.907	1.627	0.926	0.399	0.218
519	3.474	1.565	0.794	0.379	0.199
523	3.920	1.504	0.672	0.306	0.178
526	3.839	1.408	0.726	0.329	0.185
530	3.688	1.461	0.634	0.316	0.151
533	3.332	1.254	0.586	0.266	0.128
537	3.359	1.092	0.548	0.248	0.114
540	3.283	1.099	0.473	0.194	0.0832
543	2.723	0.954	0.435	0.181	0.0691
547	2.361	0.940	0.402	0.153	0.0569
551	2.494	0.761	0.325	0.122	0.0446
554	2.300	0.662	0.318	0.113	0.0377
558	1.816	0.598	0.254	0.0791	0.0280
561	1.680	0.486	0.197	0.0725	0.0205
565	1.469	0.377	0.141	0.0514	0.0134
568	1.196	0.281	0.107	0.0343	0.00833
571	0.914	0.201	0.0707	0.0228	0.00530
575	0.674	0.135	0.0454	0.0142	0.00338

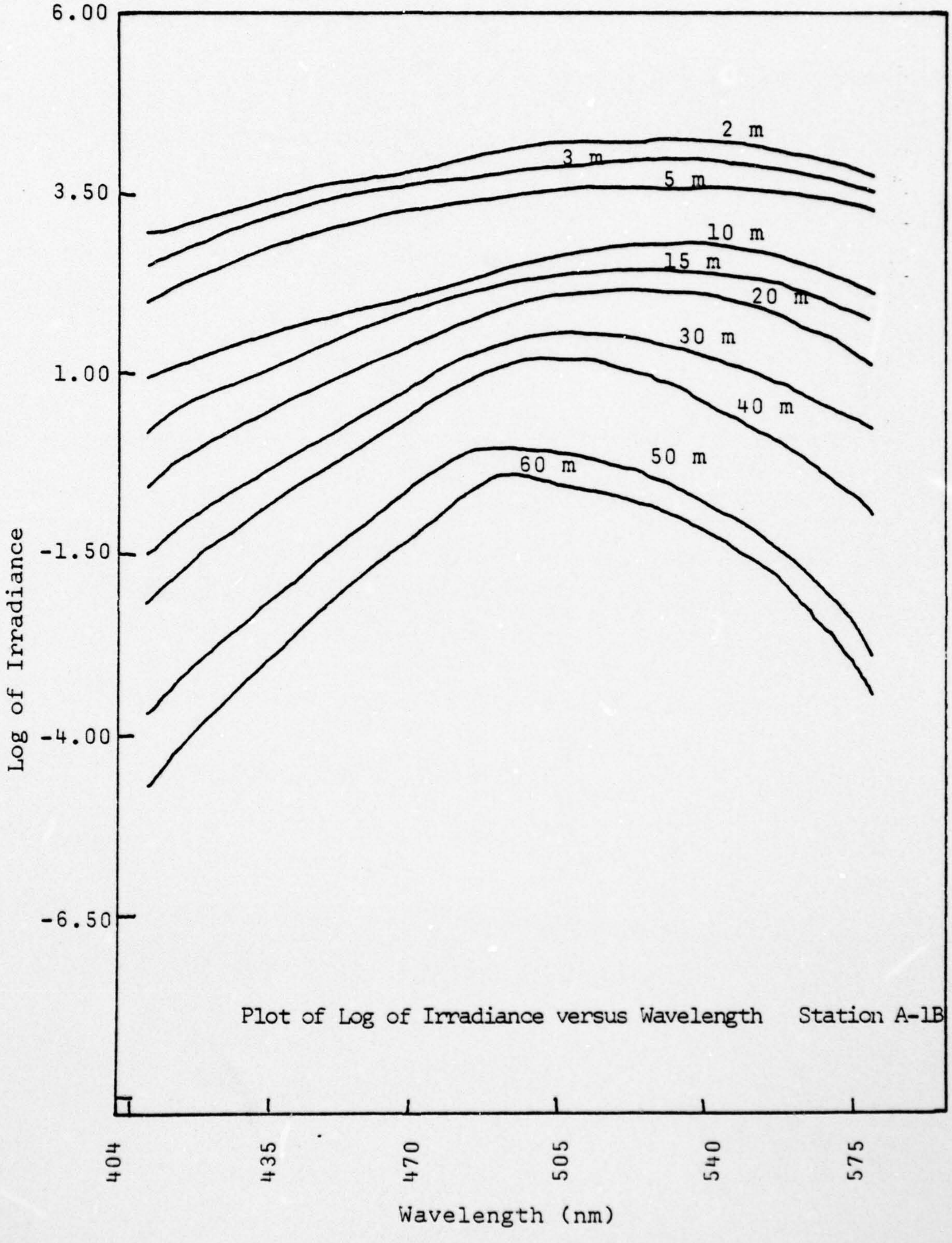

6.00
3.50
1.00
-1.50
-4.00
-6.50
Log of Irradiance
2 m
3 m
5 m
10 m
15 m
20 m
30 m
40 m
50 m
60 m
Plot of Log of Irradiance versus Wavelength Station A-1A
404
435
470
505
540
575
Wavelength (nm)

STATION A-1B   31 AUG 76   IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	2 m	3 m	5 m	10 m	15 m
404	12.648	8.397	5.901	1.309	0.775
407	12.052	9.609	7.930	1.949	1.270
411	19.196	15.213	11.477	2.460	1.521
414	20.723	14.612	10.528	2.688	1.625
418	21.007	16.038	13.666	3.328	2.174
421	24.929	17.552	11.647	3.872	2.231
425	20.519	17.326	14.717	3.029	2.527
428	21.044	21.481	16.037	4.375	2.389
432	23.961	24.545	19.630	4.309	3.233
435	19.060	20.362	20.717	4.469	3.133
439	23.813	21.626	19.545	4.732	3.578
442	26.808	28.516	22.322	5.654	4.041
446	35.400	29.011	20.037	6.485	3.842
449	32.716	31.825	26.050	6.063	5.541
453	26.281	30.095	19.464	6.841	5.081
456	29.566	33.733	27.897	7.414	5.500
460	34.970	28.997	21.147	7.980	6.003
463	34.084	32.925	23.820	7.624	5.867
467	40.785	34.747	20.570	8.331	6.062
470	37.687	32.502	24.306	9.192	7.128
474	41.046	37.476	29.066	10.567	8.467
477	46.478	34.707	33.181	9.174	9.677
481	51.419	37.029	28.241	10.768	8.868
484	57.644	37.145	31.036	11.220	9.221
487	50.013	38.284	28.403	11.165	9.885
491	46.947	40.194	28.453	11.910	10.848
495	42.217	45.267	30.580	11.618	11.713
498	41.470	51.317	35.035	11.827	9.786
502	48.075	45.243	29.037	12.522	9.443
505	40.283	36.904	25.059	11.130	9.239
509	49.629	42.624	31.150	12.141	10.376
512	50.752	37.631	25.805	10.700	9.491
516	56.320	35.680	29.182	11.363	11.039
519	43.557	37.186	31.624	14.483	9.518
523	44.148	35.333	30.701	11.264	11.174
526	38.894	36.735	27.155	11.520	11.211
530	42.031	40.902	28.104	13.979	11.887
533	35.733	33.834	28.434	12.894	10.746
537	34.057	35.975	27.416	12.532	10.252
540	34.409	39.513	28.457	12.469	10.248
543	33.407	34.189	28.687	11.900	9.840
547	30.192	34.388	29.085	11.290	9.246
551	28.347	28.913	25.623	10.105	7.986
554	24.503	27.441	24.980	10.562	7.512
558	27.424	27.347	24.869	9.712	6.259
561	31.396	28.416	23.268	9.731	6.406
565	30.371	24.904	21.332	8.069	5.549
568	27.764	23.517	19.754	6.822	4.335
571	25.669	21.969	18.995	6.682	3.271
575	24.044	18.939	18.076	4.923	2.786

STATION A-1B 31 AUG 76 IRRADIANCE VALUES ($\mu W/cm^2$-nm)
WAVELENGTH (WL) IN NANOMETERS

WL	20 m	30 m	40 m	50 m	60 m
404	0.485	0.172	0.0873	0.0218	0.00909
407	0.667	0.234	0.119	0.0271	0.0114
411	0.863	0.301	0.143	0.0352	0.0146
414	0.957	0.340	0.173	0.0433	0.0183
418	1.214	0.449	0.209	0.0568	0.0223
421	1.210	0.496	0.256	0.0653	0.0253
425	1.454	0.476	0.274	0.0720	0.0307
428	1.601	0.721	0.360	0.0902	0.0380
432	1.671	0.735	0.387	0.108	0.0447
435	1.850	0.831	0.519	0.131	0.0524
439	2.259	1.031	0.636	0.155	0.0697
442	2.966	1.189	0.740	0.213	0.0807
446	3.013	1.356	0.912	0.236	0.111
449	3.321	1.833	0.881	0.304	0.129
453	3.481	1.743	1.084	0.335	0.161
456	4.208	2.013	1.346	0.418	0.193
460	3.976	2.318	1.410	0.459	0.209
463	4.851	2.266	1.647	0.498	0.252
467	4.690	2.480	1.654	0.599	0.268
470	5.575	3.121	2.179	0.611	0.357
474	5.699	3.858	2.755	0.732	0.438
477	6.169	4.012	2.672	0.859	0.412
481	6.824	4.052	2.798	0.880	0.516
484	6.016	4.049	2.986	0.937	0.535
487	7.177	4.669	2.691	1.012	0.587
491	6.656	4.404	3.308	1.102	0.592
495	7.167	4.687	2.890	1.049	0.608
498	8.143	4.908	3.291	1.003	0.564
502	7.592	4.307	2.865	0.907	0.593
505	6.425	4.432	2.736	0.824	0.482
509	7.529	4.316	2.310	0.752	0.449
512	5.933	3.649	2.063	0.638	0.365
516	6.247	3.926	2.191	0.624	0.337
519	7.278	3.474	2.190	0.580	0.333
523	7.379	3.475	2.273	0.535	0.328
526	6.796	3.351	1.607	0.469	0.290
530	7.294	3.298	1.655	0.445	0.255
533	5.879	3.164	1.613	0.380	0.230
537	6.296	2.957	1.351	0.379	0.218
540	4.973	2.610	1.101	0.293	0.172
543	4.799	2.528	1.105	0.261	0.147
547	5.021	2.084	0.967	0.221	0.124
551	4.236	2.008	0.888	0.189	0.101
554	4.145	1.758	0.723	0.176	0.0877
558	3.382	1.368	0.550	0.138	0.0623
561	3.190	1.277	0.515	0.112	0.0492
565	2.704	1.234	0.358	0.0704	0.0320
568	2.226	0.853	0.248	0.0483	0.0206
571	1.611	0.625	0.151	0.0306	0.0127
575	1.252	0.458	0.106	0.0203	0.00774


6.00
3.50
1.00
-1.50
-4.00
-6.50
Log of Irradiance
2 m
3 m
5 m
10 m
15 m
20 m
30 m
40 m
50 m
60 m
Plot of Log of Irradiance versus Wavelength Station A-1B
404
435
470
505
540
575
Wavelength (nm)

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